



1 **Erosion risk assessment and identification of susceptibility lands** 2 **using the ICONA model and RS and GIS techniques**

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8
9 **Abstract.** Soil erosion in Iran due to the destruction of natural resources has intensified in recent years and land use changes
10 have played a significant role in this process. On the other hand, the lack of data in most watersheds to evaluate erosion and
11 sedimentation for finding quick and timely solutions for watershed management has made the use of models inevitable. The
12 purpose of this study was to use the ICONA model and RS and GIS techniques to assess the risk of erosion and to identify
13 areas sensitive to water erosion in the kasilian watershed in northern Iran. The results of this study showed that with very high
14 slope class percentage (20% - 35%) and sensitivity of shemshak formation to weathering which covers a large part of the
15 watershed, soil erodibility class is high. But there is adequate land cover along with high percentage of natural forest cover, it
16 has mitigated erosion. For this reason, the kasilian watershed is generally classified as low to moderate of erosion risk. Based
17 on the erosion risk map, results show that the moderate class had the highest percentage of erosion risk (26.26%) at the
18 watershed. On the other hand, the low erosion risk class comprises a significant portion (25.44%) of the catchment area. Also,
19 10.92% of the catchment area contains a very high erosion risk class, with most of it in rangeland and Rock outcrops second.
20 However, the erodibility of the kasilian watershed is currently controlled by appropriate land cover, but the potential
21 susceptibility to erosion is high. If land cover is reduced due to inadequate land management, the risk of erosion is easily
22 increased.

23 **1 Introduction**

24 Nowadays, with the growth and development of human activities, land use change, resource degradation and subsequent soil
25 erosion are major problems in watersheds. This will, in the long run, obstacle the sustainable development of the environment,
26 natural resources and agricultural lands. A study by Mohammadi et al. 2018 in Iran concluded that soil erosion in Iran has
27 increased in recent years due to the destruction of natural landscapes. Understanding the extent of soil erosion risk in the
28 absence of information in watersheds will enable critical areas of erosion to be identified. There is a lack of information in
29 most of Iran's watersheds (Naderi et al., 2011). To achieve these goals, it is useful to use empirical models using RS and GIS
30 techniques to estimate the sensitivity or potential of erosion risk. Numerous methods, including USLE, RUSLE, SIMWE,
31 LISEM, QUERIM, PSIAC, MPSIAC, etc. have been used to predict and evaluate soil erosion and soil conservation planning.
32 Qualitative assessment models based on the cognition that influence the factors affecting erosion can also play an important
33 role in determining priorities affecting erosion and erosion susceptibility. One of these models is the ICONA model used in
34 this study. Providing input data is a major problem that can be solved by remote sensing techniques and GIS analysis.

35 The use of RS and GIS techniques along with modeling processes such as soil erosion will accelerate the recognition, control
36 and management of natural resources. GIS and RS make spatial data analysis faster and easier, and make it possible to combine
37 extensive information across different fields and sources and simplify information management (Reis et al., 2017). In this
38 situation, it is necessary to find quick and timely solutions. One of these solutions is the use of the ICONA model. This model
39 was developed by the Spanish Society for the Conservation of Nature. Among many methods for predicting erosion using GIS
40 and RS, simulation results of this model are widely accepted (Entezari, 2017).The ICONA model is one of the simplest and

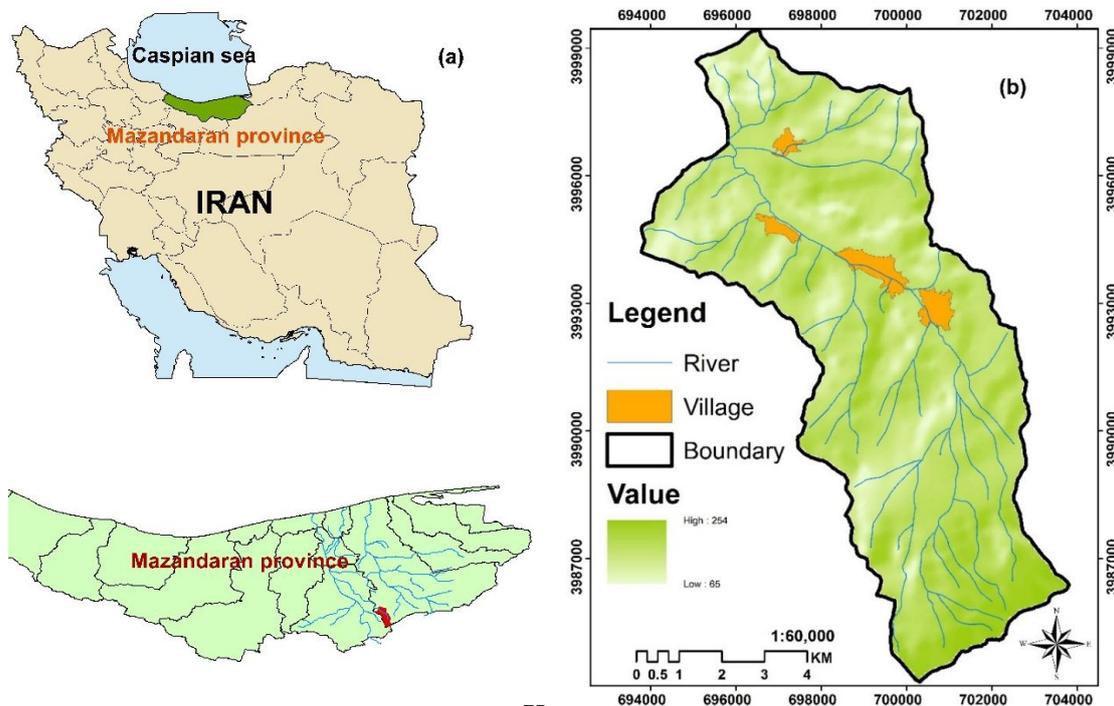


41 most flexible qualitative methods for assessing and mapping soil erosion risk. This model is useful for describing and
42 comparing soil erosion in watersheds that do not have accurate and sufficient statistics. This model is an erosion risk assessment
43 method that utilizes qualitative decision rules and hierarchical organization of the four main inputs. This model is used in
44 Europe and Mediterranean countries (Okou et al., 2016). The erosion risk map prepared with the ICONA model can be a
45 reliable framework for erosion risk assessment (Zaz and Romshoo, 2012). This flexibility model can be used in decision-
46 making to solve erosion and destruction problems in the specific circumstances of each country or region (ICONA, 1997).
47 A case study carried out in the Bata watershed in Tunisia by Kefi et al. (2009) using the ICONA model and the use of RS and
48 GIS techniques showed that the Bata area, especially in areas with high slope and low vegetation cover, there is a very serious
49 problem of water erosion. Each watershed is also important in environmental, social and economic. In this regard, by managing
50 the erosion risk zoning and identifying the erodibility status of the watershed, management can be implemented to control and
51 reduce soil erosion (Olivares et al., 2011). However, sometimes the conditions of cover, rock facies and soil of some areas are
52 such that they limit the extent of erosion severity (Chatsimab et al., 2017). A study by Sedighi (2011) in the Tangier-Red
53 watershed of Shiraz, Iran, using the ICONA model and the use of RS and GIS techniques. The results showed that the extent
54 of areas in the middle, high and high classes was increased during this time due to the change in land use. Karimi and Amin
55 (2012), in one study, zoned the erosion risk in Sivand Dam watershed in Fars province in Iran using the ICONA model and
56 RS technique. The results of this study showed that the watershed erosion rate has increased. They identified critical erosion
57 sites and proposed a management plan for it.
58 In this study, ICONA model was used to evaluate and determine the erosion risk status in kasilian watershed in northern Iran,
59 using RS and GIS techniques to determine the impact of factors affecting erosion. The ICONA model is a qualitative one, so
60 after completing the erosion risk mapping, we performed the model validation using the modified PSIAC method. In this study,
61 the soil erosion potential risk map with the ICONA model can be very important as a fast and practical method for soil
62 conservation decision makers and planners.

63 **2 Data and methods**

64 **2.1 Study Area**

65 The Kasilian Watershed is situated in the Mazandaran river watershed, one of the six major river watersheds in Iran.
66 Geographically, it lies within latitudes of 35° 58' 45" to 36° 07' 45" north, and longitudes 53° 01' 30" to 53° 17' 30' east (Fig.
67 1). The study area extends for about 6750 ha where the elevation ranges from 1100 to 2900 m.a.s.l. The area is characterized
68 by temperate climate according to De Martonne classification, while the Emberger climatic classification suggests a height
69 climate for the area (Hao and Aghakouchak, 2014; Hosseini pazhouh et al. 2018). According to a classification proposed by
70 the Natural Resources Conservation Service (NRCS), the hydrological soil group C well portrays the soil infiltration condition
71 of the study area in which a slow water infiltration and transmission rate prevails because the downward movement of the
72 water is impeded by moderately to very fine-textured soils. Also, forests, rangelands, farmlands, residential and rock outcrop
73 are the main land covers in the study area.



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76 **Figure 1:** Geographical location of the kasilian watershed in Iran (a), Geographical coordinates system of kasilian watershed (b)

77 2.2 Landsat data

78 For this study, OLI satellite images with 30 m terrestrial resolution and spectral bands were used. Landsat satellite images of the
79 study area were produced in July 2017. These data are automatically referenced to the UTM coordinate system and the WGS 1984
80 elliptic system during ground harvesting by known coordinate points. However, the accuracy of the geometric correction of the
81 images was evaluated by overlaying the correlation data vector on the false color images of 4–3–3 and the topographic map of 1:
82 50,000 using Gaussian filtering. The average RMSE (Root Mean Square Error) error was estimated to be 0.48 pixel geometric
83 correction, which is acceptable. The two-step process proposed by Chander et al. (2009) was used to perform radiometric correction
84 of images. Atmospheric correction is performed using the FLAASH algorithm. This program corrects atmospheric effects during
85 SWIR and VNIR wavelengths. This program uses the standard equation for spectral radiation in the sensor, which is intended for
86 solar wavelength ranges (other than the thermal range) at the Lambert levels. Rewritten images were also transcribed using the
87 nearest neighbor interpolation method.

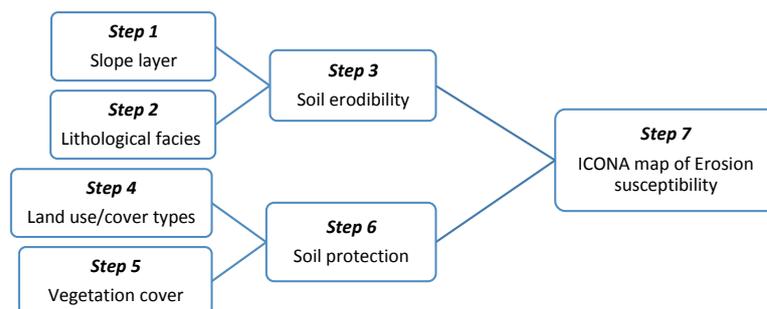
88 Training samples were prepared to map and then supervised classification was performed. Visual interpretation methods for images
89 and maps, Google Inheritance imagery, field visits and GPS pointers have been used for this purpose. More than 20 training and
90 control samples were selected for each user class. In total, 50% of the total number of samples were considered as control points. In
91 this study, Maximum likelihood method was used, which is the most suitable method for classification with supervision and its
92 classification results are produced as user maps.

93 2.3 Modelling approach

94 The ICONA model is a model developed and developed by the Spanish Institute of Natural Conservation (ICONA 1997; Bayramin
95 2003). It is a model for estimating the degree of erosion risk in watersheds that affect Its basis can be estimated at large scales of
96 erosion risk, which is applicable in European countries and many Mediterranean regions and is similar to many of the effective ways



97 to predict erosion using RS and GIS, the model was adopted in the above countries with similar climatic conditions (ICONA 1991).
98 The ICONA model consists of seven stages, as shown in Fig. 2 this is given.



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Figure 2: The methodological architecture of the ICONA model

101 Validation of the erosion risk map is an important aspect of model analysis. This can be done through quantitative evaluation
102 such as erosion measurement (Stroosnijder et al., 2003; Olivares et al., 2012; Kefi et al., 2009; Verieling et al., 2006). Due to the
103 empirical model of the ICONA model, to validate the results of this model with respect to its inputs, we evaluated the accuracy
104 of the ICONA model after preparing the erosion risk map using the modified PSIAC method. This method relies on the
105 calculation of various parameters including geology, soil, climate, surface erosion, slope, land cover, land erosion and gully
106 erosion. The erosion and sedimentation rate of the kasilian watershed after field laboratory operations were estimated according
107 to the modified PSIAC method. Validation of the erosion risk map is an important aspect of model analysis.

108 2.4 Maps construction in ICONA model

109 2.4.1 Slope map

110 In order to prepare the slope map of the studied watershed, the digital information of maps of 1:25000 Survey Organization¹ of
111 Iran was used. After preparing the digital elevation model (DEM) of the studied watershed, the slope map was obtained in
112 ArcGIS 10-3 environment. Then the watershed slope layer is produced in five classes: low and flat slope (%0-3%), medium
113 slope (3% -12%), high slope (%12-20%), very high slope (20% - 35%) And extremely high slope (more than> 35%).

114 2.4.2 Lithofacies map

115 Soil has been known to be the source of all subsequent developments in each area and it is very important to study the status of
116 the soil. The lithological units outcrop within the study area are classified according to physical and chemical resistance to
117 weathering (ICONA, 1997), which were classified into five groups. In this model we rely on different types of soil. Because
118 soils are often involved at the level of erosion processes, they constitute highly valuable and pivotal resources, and therefore our
119 classification should be based on the characteristics of the soil and the factor of soil erodibility (Okou et al., 2016). The amount
120 of soil erodibility factor was determined using USLE nomograph (Bayramin, 2003; Zaz and Romshoo, 2012). In this research
121 we used 1: 100000 maps of Iran Geological Organization².

122 2.4.3 Erodibility map

123 The soil erodibility layer was prepared by incorporating two layers of lithofacies and slope. The erodibility map indicates the

1. The use of these maps as a basic map and scientific document is free.
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124 potential (risk) of erosion in the watershed. In general, the integration of two slope and geological maps, according to the class
125 specificity of each map, constitutes $5 \times 5 \times 5$ matrix, which in total is divided into 5 classes of Very Low (EN), Low (EB), Medium
126 (EM), High (EA) and very high (EX) are divisible (Table 1, Panel I).

127 **2.4.4 Land use/land cover map**

128 Satellite imagery and remote sensing techniques have been used to map the land. In this study, Landsat OLI satellite images with
129 30 m terrestrial resolution and spectral bands were used. For each user class, more than 20 training and control samples were
130 selected. In total, 50% of the total number of samples were considered as control points. In this study, Maximum Likelihood
131 method is used, which is the most suitable method for classification with supervision and its classification results are produced
132 as user maps (Tehrany et al., 2013, 2014). Accuracy evaluation results are usually presented as an error matrix, in which case a
133 variety of parameters and values that indicate accuracy or some kind of error in the results are extracted from this matrix.

134 **2.4.5 Vegetation cover map**

135 Plants are illuminated in the range of 700 to 1,300 nm (near infrared) because they have a very high reflectance in the range,
136 reflecting the spectrum of green plants to extract vegetation mapping from the near-infrared split or band ratio process. Satellite
137 images are used for each pixel. Therefore, the Normal Vegetation Index (NDVI) provides information on the spatial and temporal
138 distribution of vegetation (photosynthesis) with photosynthetic activity and productivity (Tucker et al., 1985., Reed et al., 1994)
139 as well as the extent of land degradation in different ecosystems. It also shows (Holm et al., and Thiam, 2003). In this study, we
140 used this index for vegetation status and analyzed four classes of NDVI values for (1) low <25%, (2) moderate 25% - 50%, (3)
141 high 50% - 75% and (4) very high, more than > 75% (ICONA, 1997).

142 **2.4.6 Soil protection map**

143 At this stage, to obtain a soil conservation map, the overlay layer and vegetation layer overlap to form a $5 \times 5 \times 5$ matrix. Soil
144 protection status class according to type of use and vegetation cover (MA) Very high protection, (A) high protection, (M)
145 moderate protection, (B) low protection and (MB) very low protection (Table 1, Panel II).

146 **2.4.7 Erosion susceptibility map**

147 In the last step of the ICONA model, a erosion risk map, soil conservation map and soil erodibility map were merged to overlay
148 the GIS. Consequently, according to Table 1, Panel III, according to the specificity of the classes of each map, they produce a
149 $5 \times 5 \times 5$ matrix which, in sum, has a map of erosion risk in the 5 erosion risk classes (1) very low, (2) low, (3) Moderate, (4)
150 high and (5) very high.

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161 **Table 1:** Decision rule matrices for map overlapping

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Slope classes	Lithofacies				
	a	b	c	d	e
Flat to gentle(%0-3%)	EN	EN	EN	EN	EB
Moderate (%3-12%)	EN	EN	EB	EM	EM
Steep(%12-20%)	EB	EB	EM	EA	EA
Very steep(%20-35%)	EM	EM	EA	EX	EX
Extremely steep(>35%)	EA	EA	EX	EX	EX

II					
Land covers	Vegetation cover(%)				
	0-25%	25-50%	50-75%	>75%	
Rainfed farming	MB	MB	B	B	
Irrigated farming	MB	MB	B	M	
Forest	M	A	MA	MA	
Orchard	B	M	A	MA	
Rangeland	MB	B	M	A	
Bare land	MB	M	A	MA	
Rock outcrops	MA	MA	MA	MA	

III					
Soil protection	Soil erodibility				
	EN	EB	EM	EA	EX
MA	1	1	1	2	2
A	1	1	2	3	4
M	1	2	3	4	4
B	2	3	3	5	5
MB	2	3	4	5	5

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165 **3 Results**

166 **3.1 Modelling steps**

167 The results regarding different calculation steps of the ICONA model are explained as follows.

168 **Step 1: Slope map**

169 According to Fig. 3a and Table 2, the bulk of the study area has a very steep slope (%20-35%) of 53.8%. The high slope class
 170 (12% -20%) also comprises the second tier, equivalent to 20.2% of the area. Also, the extremely high slope ranks third (17.9%).

171 While the limited surface area of the watershed is low and flat.

172

173 **Table 2:** Areal percentages of the slope classes in the study area

Slope classes	Slope(%)	Area(ha)	Area(%)
Flat to gentle	0-3	26.98	0.4
Moderate	3-12	521.4	7.73
Steep	12-20	1363	20.2
Very steep	20-35	3632	53.8
Extremely steep	>35	1207	17.9

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176 **Step 2: Lithofacies map**

177 A map of the lithofacies of the kasilian watershed (Fig. 3b) shows that much of the watershed area, 72.6%, is composed of dark
 178 gray and sandstone shale (Table 3). These soils are from Shemshak Formation and are of moderate to loose weathering. Also,
 179 20.3% belong to Kashafud Formation which are resistant to weathering.

180 The geological units of the area have a relatively wide range of permeability, with low permeability units having the most
 181 surface expansion in the study area.

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183 **Table 3:** Areal percentage of the lithofacies classes in the study area

Classes	Materials and soil/rock resistance to weathering(lithofacies)	K factor	Area(ha)	Areal percentage in the study area
(a) Non-weathered	Conglomerate, heterogeneous sandstone, and shale with fossils and thin veins of coal (Kashafud formation)	-	1371	20.3
(b) Fractured and/or medium weathered	Thick-bedded to massive light grey limestone (Lar formation)	$0.05 < K < 0.07$	377.9	5.6
(c) Slightly to medium compacted	Dark grey shale and sandstone (Shemshak formation)	$0.1 < K < 0.2$	4898	72.6
(d) Soft, low-resistant or strongly/deeply weathered	Grey to light green limestone with intercalations of calcite-shale (Dalichal formation)	$K \sim 0.2$	57.32	0.85
(e) Loose, non-cohesive sediment/soils and detritic material	Green-tuff with a heterogeneous assemblage of marine shale (Karage formation)	$K > 0.6$	45.66	0.68

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185 **Step 3: Erodibility map**

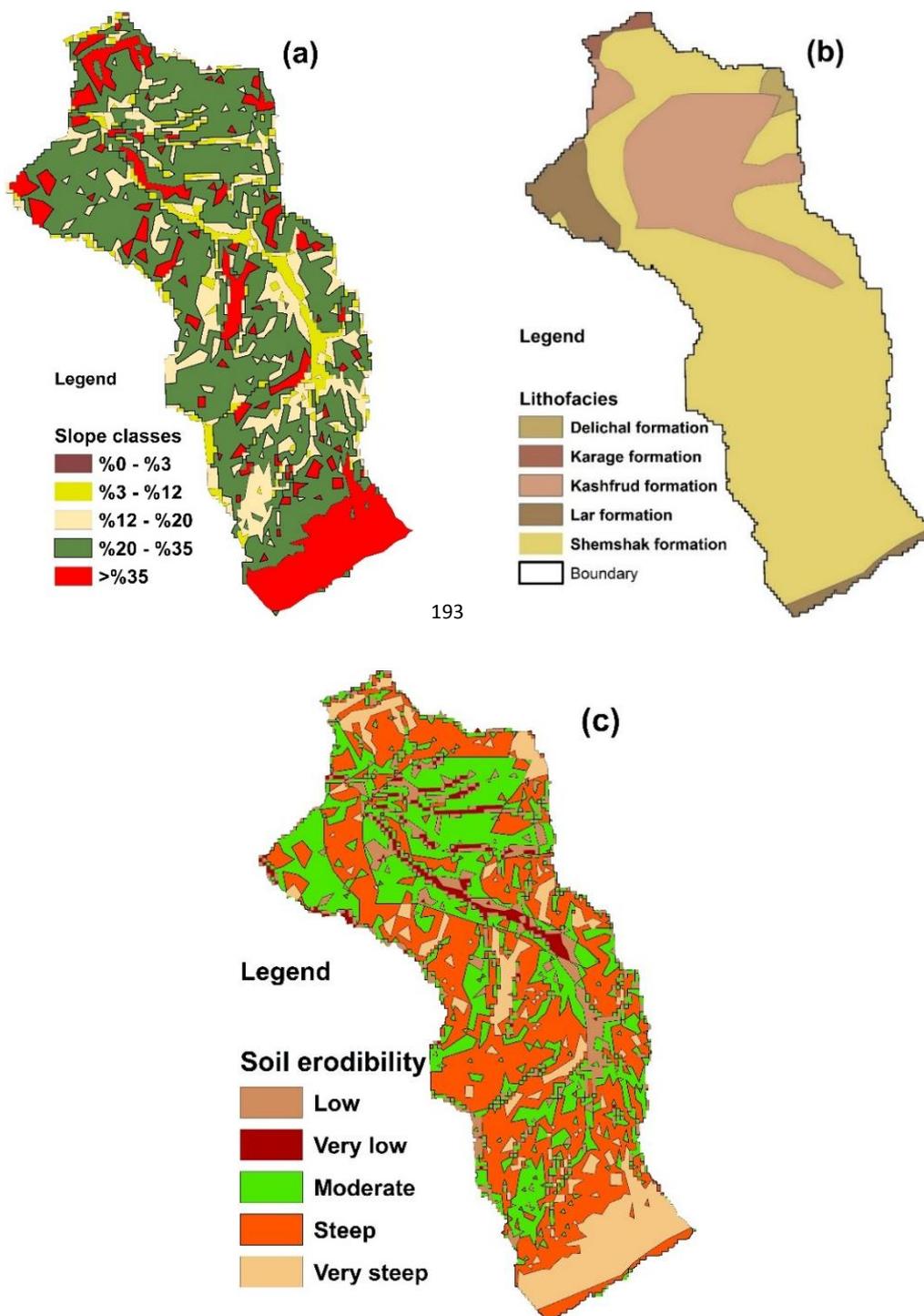
186 The soil erodibility map shows that 42.46% of the study area is highly erodible. Also, 30.58% of the watershed is in the class of
 187 moderate erosivity and only 14.71% of the watershed is highly erodible. Fig. 3c and Table 4 show the erodibility status of the
 188 study area.

189

190 **Table 4:** Areal percentage of the soil erodibility classes in the study area

Classes	Label	Erodibility	Area(ha)	Areal(%)
1	EN	Very low	186.36	2.761
2	EB	Low	641	9.496
3	EM	Moderate	2064.1	30.58
4	EA	High	2865.8	42.46
5	EX	Very high	992.78	14.71

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Figure 3: Maps of ICONA model, (a) slope map, (b) lithofacies map, (c) erodibility map



200 **Step 4: Land use/land cover map**

201 After classifying images and producing land use maps, the classification accuracy must be specified. For this purpose, kappa
 202 coefficient, overall accuracy, user accuracy and producer accuracy were calculated (Table 5).

203

204 **Table 5:** An accuracy check of the classified land use/cover types

Land use	Overall accuracy(%)	Kappa index	User's accuracy(%)	Producer's accuracy(%)
Forests	82.26	0.75	91.15	90.6
Farmlands			73	65.38
Rangelands			62.58	85.71
Residential			59.17	76.09
Rock outcrops			63	66

205 The results of Fig. 4a and Table 6 show that the highest percentage of total land use was for forest use with 67.6% followed by
 206 agricultural land. Minimum land use was also in residential areas with 2.22%.

207

208 **Table 6:** Areal percentage of the land use/cover classes in the study area

Land use	Area(ha)	Areal(%)
Farmlands	1512	22.4
Forests	4564	67.6
Rangelands	336	4.98
Residential	150	2.22
Rock outcrops	187	2.77

209

210 **Step 5: Vegetation cover map**

211 According to the results presented in Fig. 4b and Table 7, the highest percentage of vegetation based on high class NDVI index
 212 (%50-75%) with 30.44% of area and the lowest vegetation percentage. According to this index, it belongs to the middle class
 213 (%25-50%) with 19/63% of the total catchment area.

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215 **Table 7:** Areal percentage of the vegetation cover classes in the study area

Classes	Area(ha)	Areal(%)
Low(%0-%25)	1851.6	27.43
Moderate(%25-%50)	1325	19.63
High(%50-%75)	2055	30.44
Very high(>%75)	1518.4	22.5

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217 **Step 6: Soil protection map**

218 According to Fig. 4c and Table 8, 32.17% of the area has moderate protection. However, 30.91% of the area has very high
 219 protection conditions. At the same time, only 12/11% of the area is in poor conservation conditions. Therefore, a significant
 220 portion of the area is in good conservation conditions.

221

222 **Table 8:** Areal percentage of the soil protection classes in the study area

Classes	Label	Soil protection	Area(ha)	Areal(%)
1	MA	Very high	2086.5	30.91
2	A	high	967.67	14.34
3	M	Moderate	2171.3	32.17
4	B	Low	707.24	10.48
5	MB	Very low	817.28	12.11

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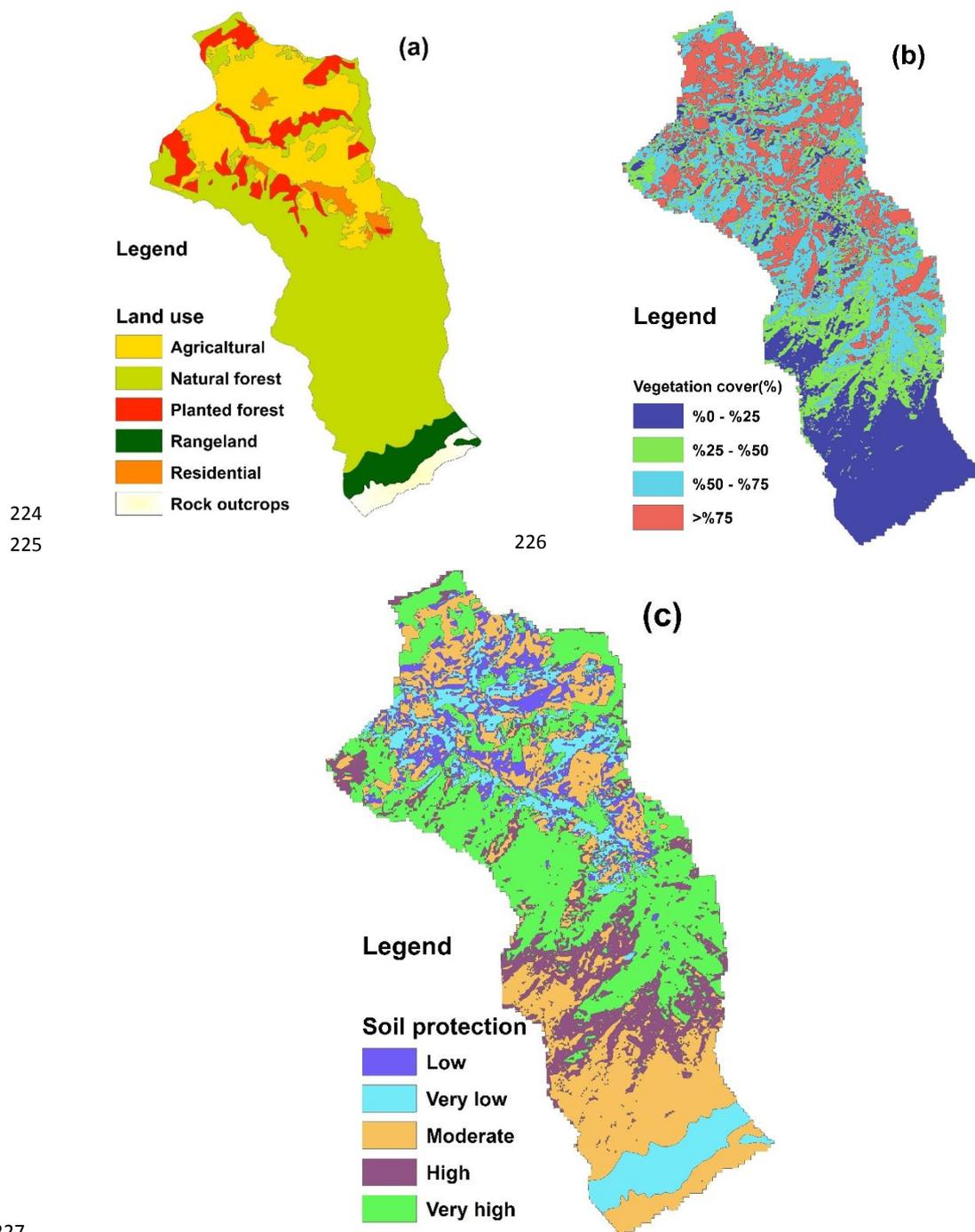


Figure 4: Protection map of ICONA model

Step 7: Erosion risk map

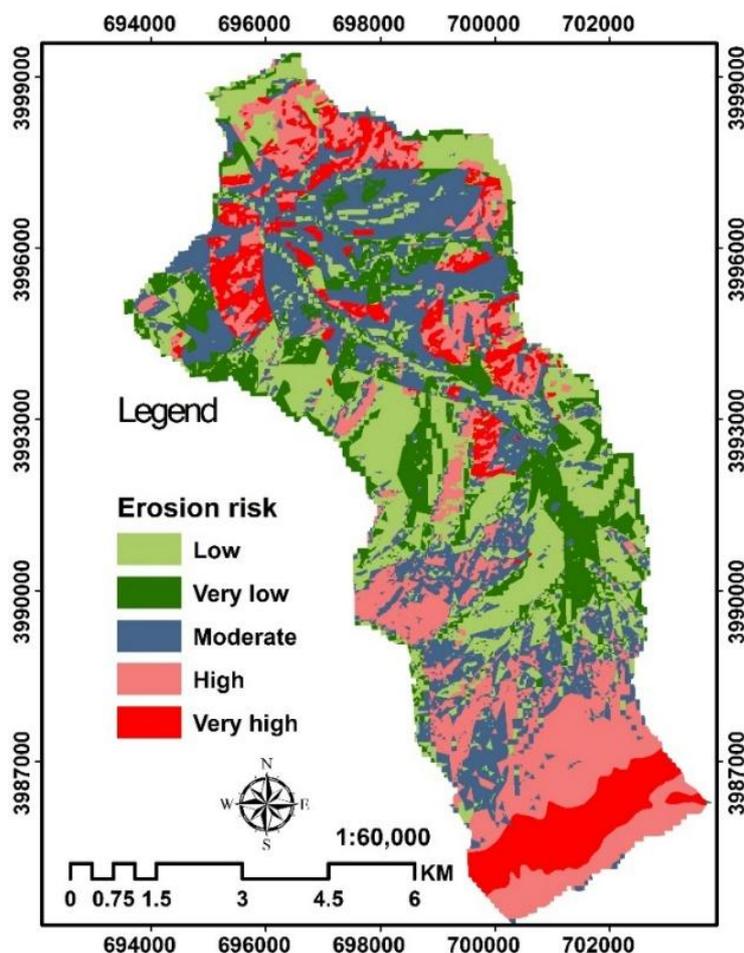
The middle class of erosion risk accounted for the largest percentage (26.26%) of the area. On the other hand, the low erosion risk class comprises a significant portion (25.44%) of the catchment area. Therefore, a significant portion of the catchment area is at moderate to low erosion risk. Only 10.92% of the area's surface constitutes a very high erosion risk class. The results of the erosion risk map are shown in Fig. 5 and Table 9.



234 **Table 9:** Areal percentage of the soil erosion classes in the study area

Classes	Erosion susceptibility	Area(ha)	Areal(%)
1	Very low	1085.8	16.09
2	Low	1717.3	25.44
3	Moderate	1772.4	26.26
4	High	1437.5	21.3
5	Very high	736.97	10.92

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Figure 5: Erosion risk map of the ICONA model

238 **3.2 Results of land consolidation with risk of erosion**

239 After preparing the erosion risk map, we combined it with the land use map. The results of the integration are presented in Table
 240 10. According to Table 10, the highest class of erosion risk in agricultural land is in the middle class (Fig. 6a).

241 According to Fig. 6b, the highest natural forest land was in the low class (20.1%) and the highest planted forest land was in the
 242 low class (3.06%). On rangeland, almost %100 of this land use is in very high erosion class. This percentage actually accounts
 243 for about 5% of the total study area (Fig. 6c). Rock outcrops comprise 99% of these lands and 2.74% of the total study area of
 244 the watershed is in high risk of erosion (Fig. 6d). Residential land is also located within the arable land and generally accounts
 245 for less than 1% of the total study area of erosion risk classes in this land use (Fig. 6e).



246 **Table 10:** Soil erosion–land use/cover matrix derived from the ICONA model

Land use	Erosion susceptibility	Area(ha)	Percentage of total land use	Percentage of total study area
Farmlands	High	322	21.3	4.77
	Low	125	8.26	1.85
	Moderate	694	45.9	10.3
	Very high	323	21.4	4.79
	Very low	48.1	3.18	0.71
Natural forest	High	891	19.5	13.2
	Low	1360	29.8	20.1
	Moderate	850	18.6	12.6
	Very high	36.9	0.81	0.55
	Very low	792	17.4	11.7
Planted forest	High	45.9	1	0.68
	Low	207	4.53	3.06
	Moderate	169	3.7	2.5
	Very high	31	0.68	0.46
	Very low	181	3.98	2.69
Residential	High	1.56	1.04	0.02
	Low	33.9	22.6	0.5
	Moderate	66	44	0.98
	Very high	6.98	4.65	0.1
	Very low	41.7	27.8	0.62
Rangelands	High	0.07	0.02	0
	Low	0	0	0
	Moderate	0.08	0.3	0
	Very high	336	100	4.98
	Very low	0	0	0
Rock outcrops	High	185	99	2.74
	Low	0	0	0
	Moderate	2.35	1.26	0.03
	Very high	0.01	0	0
	Very low	0	0	0

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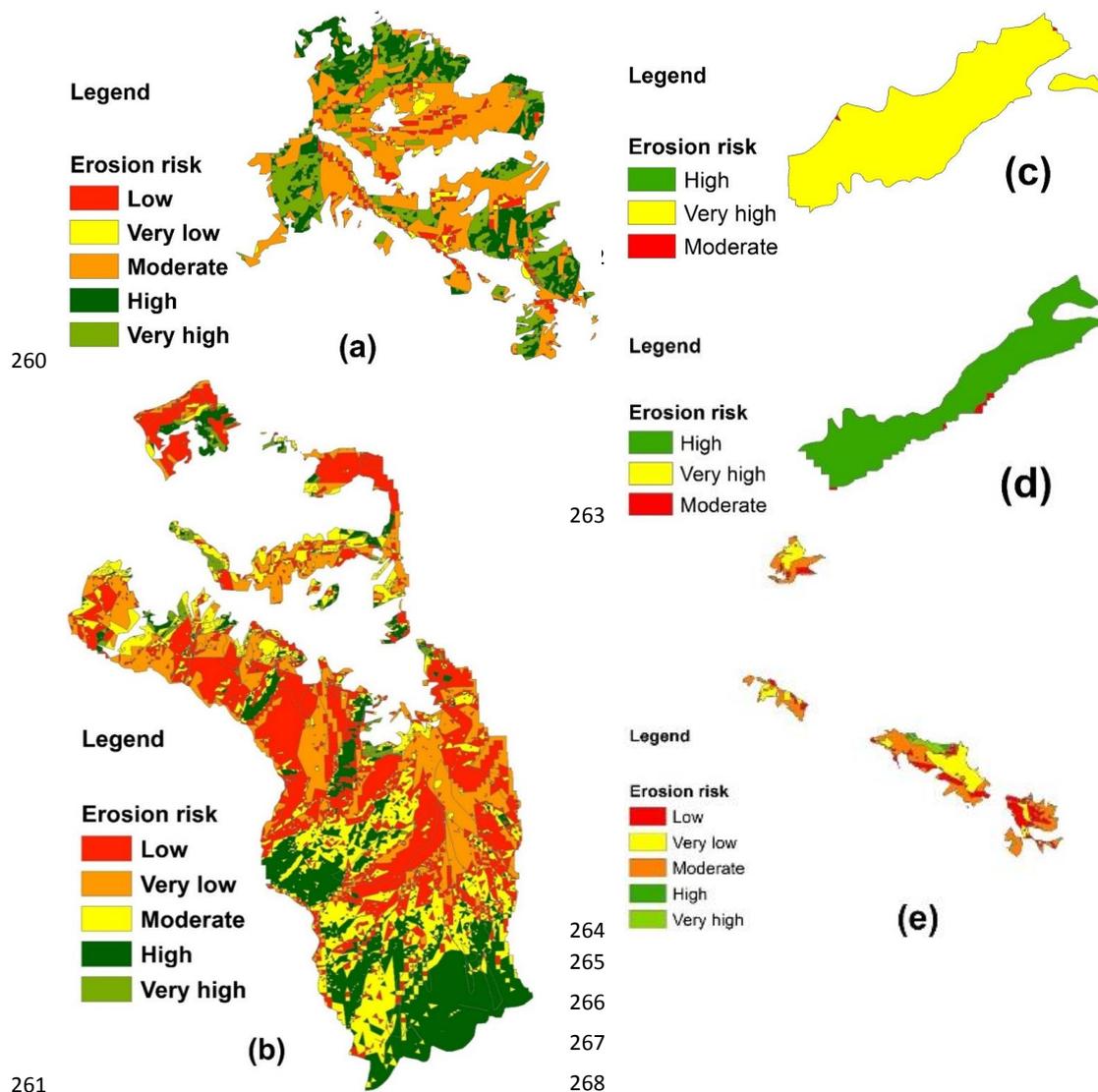
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269 **Figure 6:** Overlay erosion risk with land use map. (a) agricultural land use, (b) forests land use, (c) rangeland land use, (d) rock outcrops
 270 landuse (e) residential land use

271 **3.3 Validate the model**

272 In the study area, there is a variety of erosion occurring, indicating the influence of different factors with different intensities and
 273 weaknesses along with the impact of human factors (Fig. 7a). These factors include the type of geological formations and their
 274 degrees of susceptibility to erosion, soil type, climate, surface currents, physiographic and topographic status, vegetation and
 275 river system type. Land use and how to observe or disrupt the proper rules and principles of operation, road construction and
 276 other construction operations also play a special role in the occurrence of various forms of erosion. As can be seen, the highest
 277 erosion intensity in the region is low to moderate and high erosion intensity states are not observed in the study area. On the
 278 other hand, surface erosion and rill erosion are the most important forms of erosion.

279 In this study, the validation of the ICONA model was compared with the current risk map and the current degradation map of
 280 the study area with the modified PSIAC model. Finally, the erosion intensity map (Fig. 7b) is prepared and compared with the



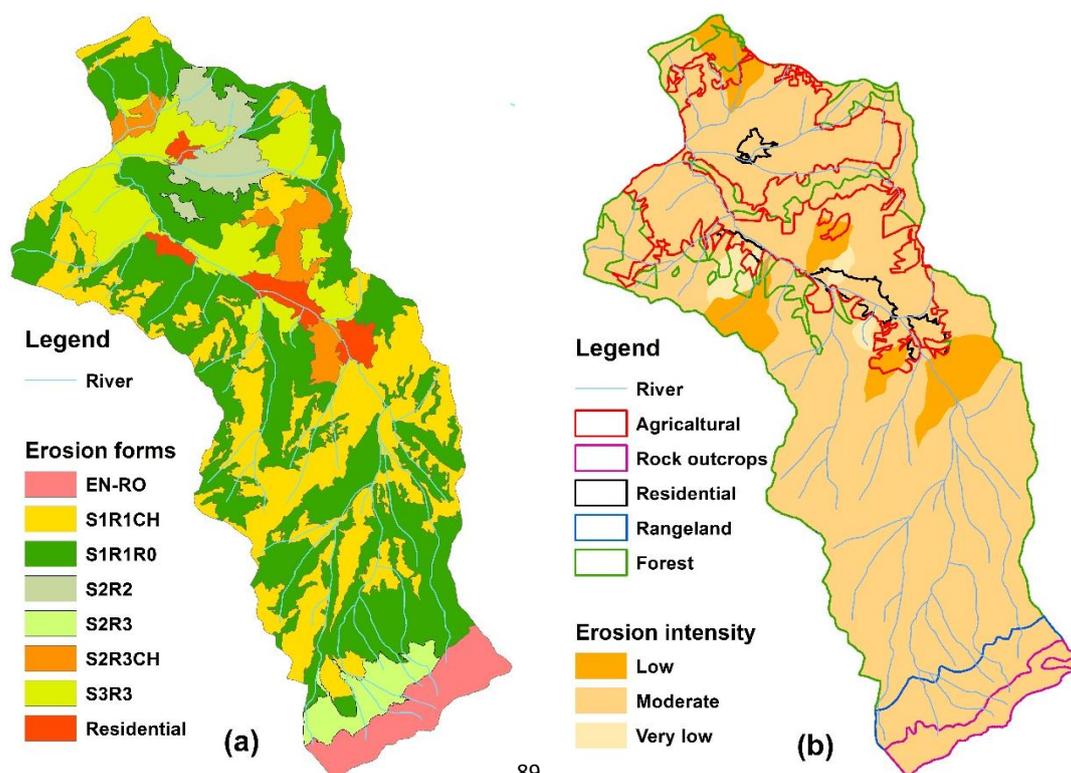
281 erosion risk map. In this study, the erosion and sedimentation rates were quantitatively and qualitatively determined using the
 282 modified PSIAC method (Table 11). The study watershed with total scores of 53.7 and specific sediment yield of 332 tons /
 283 km²/year with sum of scores of different factors can be said that the kasilian watershed is in the middle class in terms of erosion
 284 class and in low grade in sedimentation.

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286 **Table 11:** Quantitative status and quality of erosion by MPSIAC model

The severity of the erosion	Sediment production t/km ² /year	Quantitative evaluation of the effective factors on erosion
Intense	<2500	100>
Relatively intense	1500-2500	75-100
Moderate	500-1500	50-75
Low	200-500	25-50
Insignificant	200<	0-25

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Figure 7: Maps of the study area by the modified PSIAC method, (a) erosion forms, (b) erosion intensity

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291 R. rill erosion, S. surface erosion, EN. dissolution erosion, RO. rock mass loss, CH. channel erosion

292 EN-RO. Dissolution erosion and rock mass

293 S₁R₁CH. Surface, very low rill erosion along the river

294 S₁R₁RO. Surface, rill erosion with very low intensity and rock mass loss

295 S₂R₂. Surface and rill erosion with low intensity

296 S₂R₃. Low intensity surface and medium intensity rill erosion

297 S₂R₃CH. Low intensity surface, medium intensity riverbed and riverbank

298 S₃R₃. Surface and rill erosion of medium intensity

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303 4 Discussion

304 The results show that the study area has a high slope percentage. Extreme slope class (%20-35%) with an area of 3632 ha (53.8%
305 of total study area) has increased susceptibility to erosion (Fig. 3a and Table 2). The oldest geological units of the basin belong
306 to lithofacies of Shemshak Formation and the most recent are alluvial sediments in the rivers of the region. The Shemshak
307 Formation extends over 4800 ha in the basin. In terms of erodibility, most of the catchment area with the Shemshak Formation
308 is located in relatively erodible units and comprises more than 72% of the area (Fig. 3b and Table 3).

309 The high slope and high surface area of the Shemshak Formation, which is sensitive to weathering, has increased the sensitivity
310 and erodibility of the basin. The erodibility map of the basin indicates that a significant portion of the catchment area has high
311 erosivity (42.46%) (Fig. 3c and Table 4). But according to Fig. 4c and Table 8, the presence of moderate (32.17%) and very high
312 (30.91%) protective cover with high percentage of forest cover (67.60%) moderated the erosion. Forests are at low risk of erosion.
313 This study shows the positive impact of natural vegetation on reducing erodibility and erosion risk by investigating land use in
314 the kasilian watershed. In fact, areas with less vegetation suffer from more soil erosion (Lu et al., 2014; Uruk et al., 2012).
315 According to Table 6, %22.4 of the soil surface cover is represented by various human uses with the threat of human erosion.
316 The highest percentage of land use (45.9%) is in the middle erosion risk class (Table 10).

317 Also, according to Table 10, the results show that the highest and highest erosion risk classes, namely the areas most susceptible
318 to erosion caused by agricultural operations in the study area, are 645 ha in total. Therefore, with operations in the field, it can
319 be said that part of the agricultural activities in the steep slopes are unfavorable, which is very sensitive to erosion.

320 The findings showed that erosion is high in areas with high slope and low protection. This result is in agreement with the results
321 of Kefi et al. (2009). This issue (impact of high slope and low protection) is also reported from the evidence of studies by Gatib
322 and Larabi (2014) in Morocco and Volka et al. (2015) in Ethiopia working on the risk of erosion.

323 Although the climate conditions of the kasilian watershed are different from those, but in the kasilian watershed surveys, slopes
324 of more than %35 constitute %17.9 of our study area. In these areas, the study area has a low risk of erosion on surfaces with
325 high slope coverage. According to Okou et al. (2014) higher slope can also provide a natural protection against soil erosion. In
326 higher elevation areas with more sensitive ecosystems such as grassland and rock outcrops, erosion-sensitive areas depend on
327 soil status, slope, and type of land cover (Stanchi et al., 2013). By studying the kasilian watershed, the results show that the
328 rangelands and outcrops in the upstream sections of the kasilian watershed are classified as high erosion (rock outcrop) and very
329 high (rangeland) that have these special conditions (Table 10).

330 In the study area, there is a variety of erosion occurring, indicating the influence of different factors with different intensities and
331 weaknesses along with the impact of human factors (Fig. 7a). The highest erosion intensity in the region is in the low to medium
332 range and there is not much erosion. On the other hand, surface erosion and rill erosion are the most important forms of erosion
333 in the area. Based on Table 11, with the assessment of erosion status at kasilian watershed, it can be concluded that the study
334 area with a total score of 53.7 and specific sediment yield of 332 ton / km²/year was qualitatively in moderate erosion class and
335 in terms of sediment yield. The lower class is located (Fig. 7).

336 These results are in agreement with the results of the ICONA model. The highest percentage of erosion risk is in the wasilian
337 watershed with the ICONA model in the middle class and in the second in the low class. This demonstrates the validity of using
338 the ICONA model in the kasilian watershed.

339 5 Conclusion

340 The kasilian Watershed is located in the upstream areas of northern Iran with forest, agricultural, residential, pasture and rock
341 outcrops. The majority of the study area (53.8%) has a very steep slope (%20 - 35%). Soils are susceptible to erosion in this
342 basin. But by evaluating the ICONA model data, by evaluating other factors such as geological formations, vegetation cover and
343 soil protection map, these factors have suitable conditions that can modulate the effective slope factor in erosion. This process



344 has reduced the area's sensitivity to erosion. Overall, the middle class of erosion risk accounted for the largest percentage
345 (26.26%) of the study area. The low erosion risk class (25.44%) also covers a significant portion of the catchment area. Only
346 %10.92 of the catchment area of the class is at high risk of erosion, with most of it in rangeland. Rangeland ranks first in terms
347 of risk of erosion. Rock outcrops are also classified as high risk of erosion. Field studies revealed that inappropriate farming
348 operations on steep slopes, excessive use of rangelands, and the existence of dissolution erosion in rock outcrops along with a
349 slope class greatly increased the sensitivity of these uses to erosion. It is suggested that more attention be paid to the study of
350 livestock grazing management and slope management. But most of the basin is not very eroded due to favorable conservation
351 conditions and suitable vegetation.

352 This study demonstrates that the erosion risk map prepared by the ICONA model using the RS and GIS techniques in the kasilian
353 watershed is sufficiently accurate. This model can be used as a reliable framework for erosion risk assessment and enables the
354 identification of potential erosion-prone areas. It can also be used as a watershed management approach for decision makers and
355 planners in watersheds as a fast and practical approach with reduced cost and time and good accuracy and capability utilizing
356 RS and GIS techniques.

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360 **Data availability.** Due to the nature of this research, the data used is mostly in the form of layers of maps that have been used
361 in the ICONA model. Erosion and sediment data have also been used to validate the model in the study area. This data can also
362 be viewed at <http://hosseingholzam.blogfa.com>.

363 **Author contributions.** HEG first suggested the subject of the research title. The research draft was then prepared and approved
364 by other authors (HA, AM and BMV). HEG prepared the initial data. During several stages of visiting the study area, the
365 necessary data were received from the field. AM analyzed satellite image data. BMV analyzed Numerical data. HA also did
366 model analysis and model validation. Finally, all authors contribute to the final analysis and final version of the article.

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369 **Competing interests.** The authors declare that they have no conflict of interest.

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