Haji, K., Khaledi Darvishan, A., Mostafazadeh, R. (2022). Identification of erosion critical areas based on soil erodibility and terrain influence factors in the Iranian part of the Caspian Sea Basin. Agriculture and Forestry, 68 (2): 35-47. doi:10.17707/AgricultForest.68.2.03

DOI: 10.17707/AgricultForest.68.2.03

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IDENTIFICATION OF EROSION CRITICAL AREAS BASED ON SOIL ERODIBILITY AND TERRAIN INFLUENCE FACTORS IN THE IRANIAN PART OF THE CASPIAN SEA BASIN

SUMMARY

Understanding the contribution of different land uses in soil erosion leads to optimal management and conservation practices to reduce the severity of erosion and consequently, the sustainable management. Changeability of the most effective factors on soil erosion especially soil erodibility and topography in different land uses is a first step to have a general view of soil erosion in the watersheds. Therefore, the present research was carried out to study the soil erodibility (S) and terrain influence (T) factors in different land uses in the Iranian part of the Caspian Sea Basin and identification of erosion critical areas based on topography and soil erodibility factors. In order to prepare land use, S and T maps for the study area, were prepared by using satellite data of moderate resolution imaging spectroradiometer (MODIS), shuttle radar topography mission (SRTM 90m) and harmonized world soil database (HWSD) and the use of geographic information system (GIS) and remote sensing (RS), respectively. The results showed that the mean soil erodibility in the Iranian part of the Caspian Sea Basin varied from zero (soilless areas) to 0.044 (t ha hr ha^{-1} MJ^{-1} mm^{-1}). While, among eight studied land use, the highest and lowest mean values of soil erodibility were obtained in the rangeland and permanent snow-water body equal to 0.040 and zero (t ha hr ha^{-1} MJ^{-1} mm^{-1}), respectively. Also, the mean terrain influence (T) factor varied from 0.01 to 35.83 and shows more changeability in the study basin. As a result, by considering the high soil erodibility and terrain influence, the maximum erosion potential in the study area are located in the middle parts of the basin, where the highest slope gradients have high soil erodibility values. These areas are mainly located in the south slopes of the Alborz mountains. In this regard, defined critical regions based on topography and soil erodibility factors along with natural and anthropogenic factors can be considered in the planning of soil erosion control in watersheds and soil and water conservation programs.

Keywords: Land use, Management practices, Satellite data, Soil erodibility, Topography.

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Received: 27/02/2022 Accepted:23/05/2022

INTRODUCTION

Soil erosion is one of the most significant forms of land (soil truncation, loss of fertility, slope instability) and is greatly influenced by biodiversity, land use and management (Solaimani *et al*., 2009; Spalevic *et al*., 2013; Behzadfar *et al*., 2014; Chalise *et al*., 2018; Lense *et al*., 2020; Spalevic *et al*., 2020; Spalevic *et al*., 2021; Stefanidis *et al*., 2022). It is likely to be exacerbated by extensive human activities and global warming (Rosas and Gutierrez, 2019), and is a serious problem in developing countries (Chalise *et al*., 2019; Khaledi Darvishan *et al*., 2019). Soil erodibility (S) can be viewed as the integral result of the processes determining the infiltration of rain into the soil and of the processes determining the soil's resistance to the detachment of its particles and their subsequent transport (Renschler *et al*., 1999; Karami *et al*., 2018). It is generally considered as an inherent soil property with a constant value for a given soil type and widely adopted as an important factor in soil erosion prediction models (Kulikov *et al.,* 2017; Dutal and Reis, 2020). It is closely related to the basic physico-chemical characteristics of soils. Soil erosion is not only different for various types of soils, but also it is different for the same type of soil under different climate conditions or land use management. Different land use systems might alter several soil properties and processes (Karami *et al*., 2018; Tavares *et al*., 2019; Ouallali *et al*., 2020; Lense *et al*., 2021; Costea *et al*., 2022). The most important driving forces for soil erosion in Iran include soil vulnerability, land use change, unnecessary and improper development of infrastructures and illegal exploitation of natural resources (Sadeghi, 2009).

Both topographic factors, such as slope gradient and altitude, and anthropogenic factors, such as land use change, poor plant coverage, and inadequate erosion control measures, are primary reasons for soil erosion (Reis *et al*., 2017; Billi & Spalevic, 2022). The annual soil loss amounting from arable lands is 75 billion tons and costs approximately $400 billion each year in agricultural production worldwide (Wang and Zhang, 2021). To carry out a suitable plan for the management of degraded slope lands to control erosion rates and loss of productivity, it would require first a realistic assessment of soil degradation by assessing the risk of erosion in the target area. This is the main objective that can be achieved according to many previous studies by direct field and laboratory measurements of soil erodibility (Aburas *et al.,* 2020). Therefore, information about soil erodibility is the main necessity for an assessment of the soil degradation process and conservation techniques in a watershed (Vaezi *et al*., 2016) and also preventing reservoir siltation (Stefanidis and Stefanidis, 2012). Identification of critical area is an important procedure to control runoff and erosion phenomenon and considered as effective way in management of watersheds and achieving sustainable development (Mostafazadeh *et al*., 2017). Hence, studies on soil erodibility have been conducted by many researchers in the world. Therefore, the always growing availability of earth observation (EO) data and technological advancement lead to the development of automated geospatial workflows in order to fasten soil loss estimation (Stefanidis *et al*., 2021).

The effects of land management on soil erodibility in a part of Zayandeh-Rood watershed showed the average soil erodibility of 0.05 (ton h MJ-1 mm-1) in good pasture and 0.09 (t h MJ^{-1} mm^{-1}) in pasture land use and 0.09 (t h MJ^{-1} mm^{-1}) in degraded pastures (Karami *et al*., 2018). They found that the low soil organic matter content in the degraded pastures land is probably caused by livestock overgrazing and ultimately grazing. Evaluation of the soil erodibility of unpaved road slopes at the Bom Jardim city in the mountain region of the state of Rio de Janeiro showed the highest erodibility of the C horizons in relation to the other horizons of the Oxisol and Ultisol studied (Lima Soares *et al*., 2018). This fact explains the main process of observed instability, erosion at the toe of the slope and fall of the upper horizons. These results highlighted the anthropogenic effects and land use changes on soil erosion.

The effects of land use on soil erodibility in the Mediterranean highland regions of Turkey were determined by Dutal and Reis (2020). The results showed that the average erodibility (USLE-K) value was 0.09 for forest, while it was 0.12 and 0.22 for pasture and agriculture, respectively. The difference between agriculture with forest and pasture was statistically significant, while no statistically significant difference was found between forest and pasture in the study area. Parmar and Sharma (2020) calculated soil loss and soil erodibility for different crops, nutrient managements, soil series and four different slope gradients (0.5, 1≤ to <3, 1≤ to <3 and >5 %) and showed that soil loss decreased with decreasing slope gradient. The soybean cropping found more vulnerable to the soil loss whereas the orchard system found safest for soil erosion.

Soil legislation is of great importance around the globe to limit the amount of soil loss. Although there are many studies on the relationships between land use and soil erodibility, but no study has been reported yet regarding the effects of land use change on soil erodibility in Caspian Sea Basin. Therefore, the objective of this study was identification of erosion critical areas based on soil erodibility and terrain influence factors in the Iranian part of the Caspian Sea Basin.

MATERIAL AND METHODS

Study area

The Iranian part of the Caspian Sea Basin with an area of 176393.9 km^2, covers about 10% of the total area of the country and lies between 35º-39º 45′ N-latitude and 44º-59º 05′ E-longitude (Figure 1). Compared to the other parts of the country, this region has relatively more hydrometric stations and larger recorded rainfall and runoff data. With a permanent river network as well as productive farmlands, rangelands and forests, this region is of a major interest. The study basin has a complex topography with a diversity of slopes and average slope gradient of 26 %. The altitude ranges between -28 (Caspian coast) to 5671 m (Mount Damavand) and the average altitude of the study area is 1195 m. A total of 54 synoptic weather stations are operated in the study area (Chavoshi *et al*., 2013). Figure 1 shows the location of the Caspian Sea Basin among all mega-basins of Iran. The land use of the study area and also, S and T raster maps were prepared. Then, the distribution of S and T values for each land use were calculated.

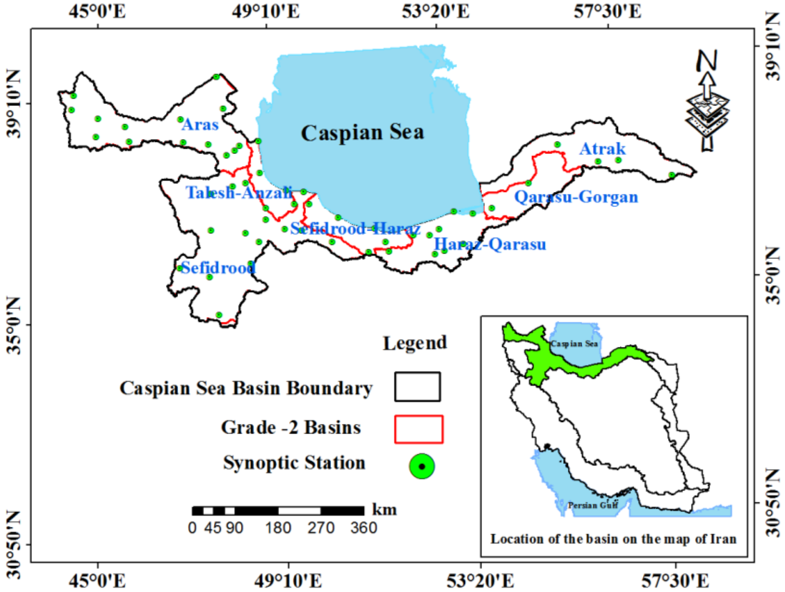

Figure 1. The location of the Caspian Sea Basin among all mega-basins of Iran

Land use map

Land use plays a critical role in soil sensitivity analysis. As a result, land should be properly used in terms of its ability and limitations, otherwise it will cause severe soil erosion (Mostafazadeh *et al*., 2017). The availability of land use information permits decision-makers to develop plans in short to long-term period for the conservation, sustainable use and development of natural resources and watersheds (Talebikhiavi *et al*., 2017; Kuriqi and Hysa, 2021). In this study, image interpretation from moderate resolution imaging spectroradiometer (MODIS) data was used to prepare land use map of the Iranian part of the Caspian Sea Basin for the year 2018. The MODIS land cover type product (MCD12Q1) supplies global maps of land cover at annual time steps and 500m spatial resolution (Sulla-Menashe and Friedl, 2018). The MCD12Q1 product is created using supervised classification of MODIS reflectance data (Friedl *et al*., 2010). Also, modifications and updates in Google Earth software used and classified to land use eight studied. Finally, ArcGIS 10.5 software were used for land use mapping (Figure 2).

Soil erodibility (S) map

Soil erodibility (denoted as the K-factor in the USLE and the S-factor in the G2 model) is best estimated from direct measurements of natural plots (Panagos *et al*., 2014). As this is not financially sustainable at the regional/national level, the S-factor Equation (1) relates to soil properties as proposed for the USLE model by Renard *et al*. (1997):

$$S = \left[\frac{2.1 * 10^{-4} * M^{1.14} * (12 - OM) + 3.25 * (s - 2) + 2.5 * (p - 3)}{100} \right] * 0.1317 \quad (1)$$

where, K: soil erodibility (t ha hr ha^{-1} MJ^{-1} mm^{-1}); M: textural factor defined as percentage of silt plus very fine sand fraction content (0.002-0.1 mm) multiplied by the factor: 100 - clay fraction; OM: organic matter content in percent (%); s: soil structure class (s = 1: very fine granular, s = 2: fine granular, s = 3: medium or coarse granular, s= 4: blocky, platy or massive); and p permeability class (p = 1: very rapid, …, p = 6: very slow) (Panagos *et al*., 2012). In the present study, the soil data of the study area was extracted from the Harmonized World Soil Database (HWSD).

Terrain influence (T) map

To estimate the influence of topography on erosion risk (T-factor, or terrain influence, or LS as denoted by the USLE), the G2 model uses an equation developed and proposed by Desmet and Govers (1996):

$$T = \left(\frac{A_S}{22.13}\right)^{0.6} * \left(\frac{\sin b}{0.0896}\right)^{1.3} \quad (2)$$

where, T: terrain influence (dimensionless, ≥0); As: unit contributing area, or flow accumulation (the numbers of upstream cells flowing into a specific cell, in m^2/m); and b: slope gradient (rad). Equation (2) is an adaptation of the Moore and Burch (1986) algorithm for spatially distributed USLE applications to grid systems. The method estimates T values equivalent to length and steepness (LS) values resulting from the original USLE formulas. The flow accumulation layers for every basin were computed from a Shuttle Radar Topography Mission (SRTM 90m) digital elevation model (DEM).

Two factors (L and T) were extracted from satellite image data and S-factor was extracted from HWSD using the ArcGIS10.5 software (Table 1).

Table 1. Summary of the input data for final mapping (Karydas & Panagos, 2018)

Factor type	Input data	Scale	Range	Dimensionality*	Source
Dynamic	Land use derived from MODIS satellite data (L)	Pixel size 1 km	[1,+∞]	0	http://earthexplorer.usgs.gov
Static	Soil Parameters (S)	Cell size 1 km	[0, 0.1]	[M] $[L^{-1}]$ $[P^{-1}]$	http://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/harmonized-world-soil-database-v12/en/
	DEM extracted from SRTM satellite (T)	Pixel size 90 m	[0, 200]	0	http://earthexplorer.usgs.gov

*P: Power; L: Length; M: Mass

Erosion potential map

After preparing and classification of each layer according to the conditions of the region and the range of numbers obtained, the final map of erosion potential by overlaying the layers (T and S factors) was prepared and classified into different classes of erosion potential based on multiplying soil erodibility and terrain influence factors. The values of K-RUSLE or S-G2 (soil erodibility) and LS-RUSLE or T-G2 (topography) factors in a given area do not change in the short term. Therefore, based on the conditions of the study area as well as land use status, it is necessary to identify the critical areas in order to implement of the control and protection operations in these areas (Fagbohun *et al*., 2016).

RESULTS AND DISCUSSION

The present study was performed to assess soil erosion potential based on soil erodibility (S) and terrain influence (T) factors for each individual land use in the Iranian part of the Caspian Sea Basin. Figure (2) shows the land use map of the study area. The lower soil erosion rates in the forests, is because of increasing the vegetation retention value which prevents of soil loss in this land use. But it is very important to note that without vegetation cover, the soil erosions rates even in the forests may be very high potentially specially where the soil erodibility and slope gradient is high enough to increase soil erosion.

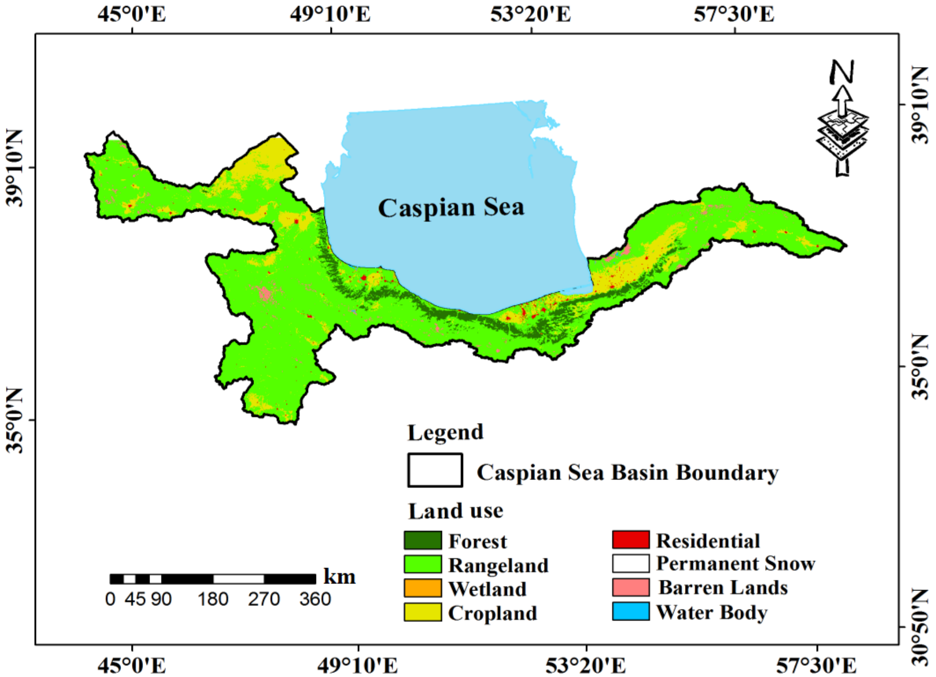

Figure 2. Land use map in the Iranian part of the Caspian Sea Basin

The terrain influence factor (T) of the Iranian part of the Caspian Sea Basin is shown in Figure (3). The mean value of terrain influence factor varies from 0.01 to 35.83 in various land uses. The lowest values of terrain influence factor are related to the flat regions (Alamdari *et al*., 2013), while the highest values of terrain influence factor (T) are related to the steep and long slope regions (Alborz mountains). In other words, in flat regions the effect of terrain influence on soil erosion value may less than the effects of rainfall intensity, soil type and vegetation. The effect of topography factors on soil loss were mentioned by other researchers (Biswas and Pani, 2015; Chalise & Kumar, 2020; Parmar and Sharma, 2020).

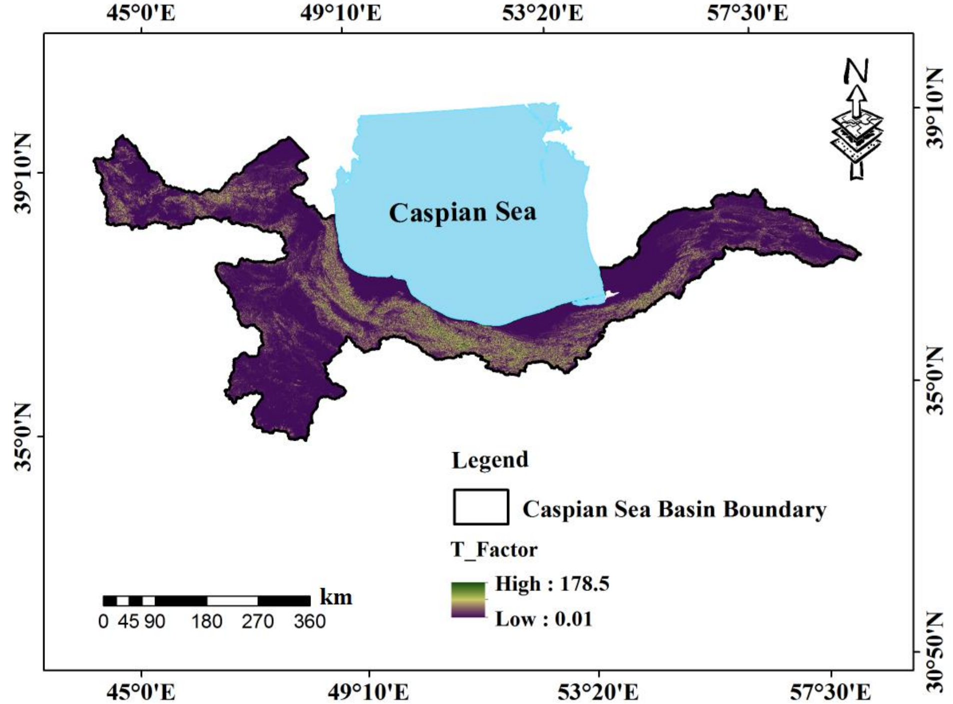

Figure 3. Terrain influence factor map (Iranian part of the Caspian Sea Basin)

Figure 4 shows soil erodibility factor (S) map in the Iranian part of the Caspian Sea Basin. Most of the dominant soils in Iran territory have less than 2% organic matter. Therefore, these soils have relatively weak soil structure and high erodibility and are sensitive to erosion. The results of the present study show that the soil erodibility value in the Iranian part of the Caspian Sea Basin ranged from zero (no soil regions) to 0.044 (t ha hr ha^{-1} MJ^{-1} mm^{-1}).

The mean values of soil erodibility (S) and terrain influence (T) factors in different land uses in the Iranian part of the Caspian Sea Basin are shown in Table 2. Among eight studied land uses, the rangeland has the highest area in the study basin (about 77 %). Also, the highest and lowest mean values of soil erodibility factor were obtained in the rangeland (0.040 t ha hr ha^{-1} MJ^{-1} mm^{-1}) and permanent snow - water bodies (zero t ha hr ha^{-1} MJ^{-1} mm^{-1}), respectively. These results confirmed the findings reported by Taleshian Jeloudar *et al*. (2018). While the highest and lowest mean values of terrain influence factor (35.83) were obtained in the permanent snow areas (peak and steep slopes of the mountains) and water bodies (0.01), respectively.

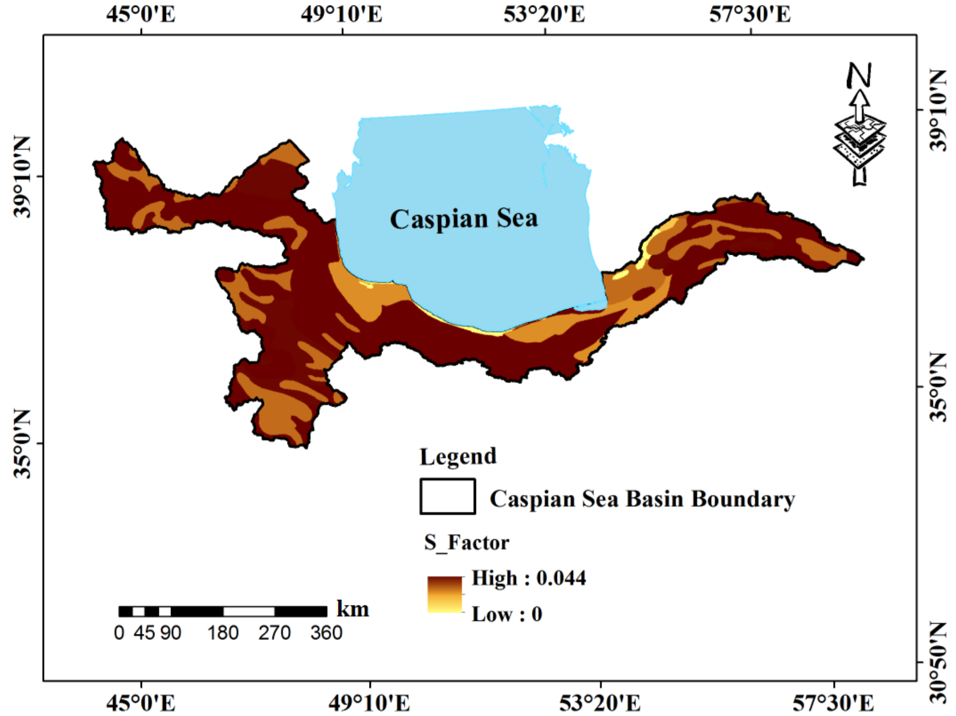

Figure 4. Soil erodibility factor (S) (Iranian part of the Caspian Sea Basin)

Whereas, with increasing terrain influence factor, runoff and soil erosion are increased too, but due to freezing soil and very low soil erodibility, the areas with permanent snow in mountain regions are not considered as critical area. The mean values of soil erodibility (S) and terrain influence (T) factors in different land uses in the Iranian part of the Caspian Sea Basin are shown in Table 2. The erosion potential map of the study area based on multiplying the soil erodibility (S) and terrain influence (T) factors is shown in Figure 5. Erosion critical areas (%) for T×S > 1.34 in different land uses of the Iranian part of the Caspian Sea Basin are shown in Figure 6.

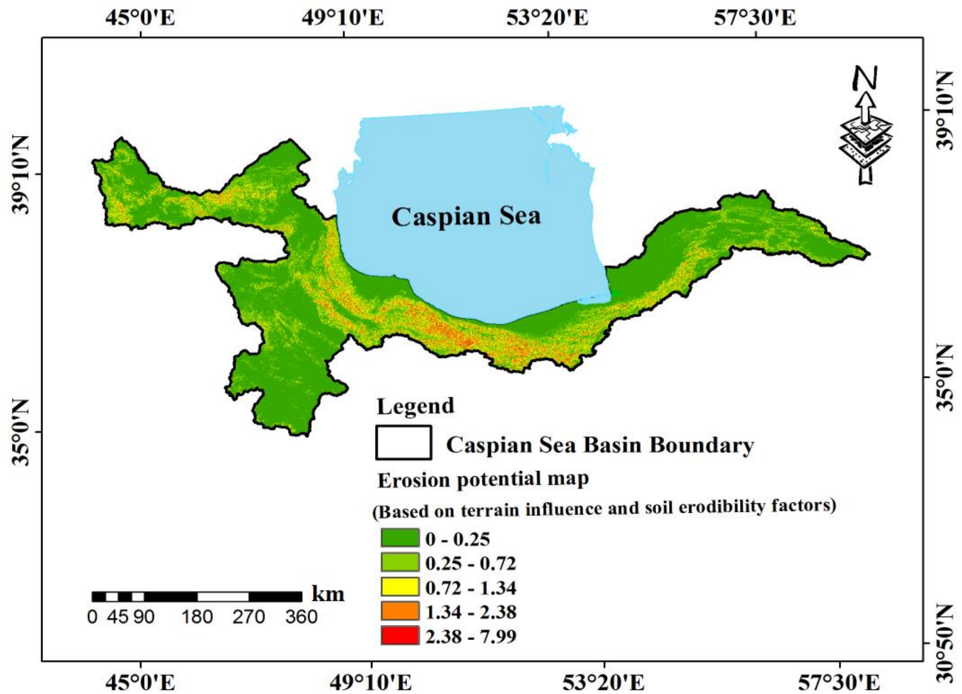

Figure 5. The erosion potential map (based on multiplying soil erodibility and terrain influence factors) in the Iranian part of the Caspian Sea Basin

Table 2. The mean values of soil erodibility (S) and terrain influence (T) factors in different land uses in the Iranian part of the Caspian Sea Basin

Land use/Land cover	Area (Km^2)	Soil erodibility (S) (t ha hr ha^{-1} MJ^{-1} mm^{-1})	Terrain influence (T)
Forest	10632.1	0.038	19.28
Rangeland	135543.7	0.040	7.72
Wetland	271.8	0.020	0.09
Cropland	25624.1	0.037	3.35
Residential	1353.8	0.028	0.50
Permanent snow	1.81	0.000	35.83
Barren lands	2695.1	0.036	6.74
Water body	271.5	0.000	0.01

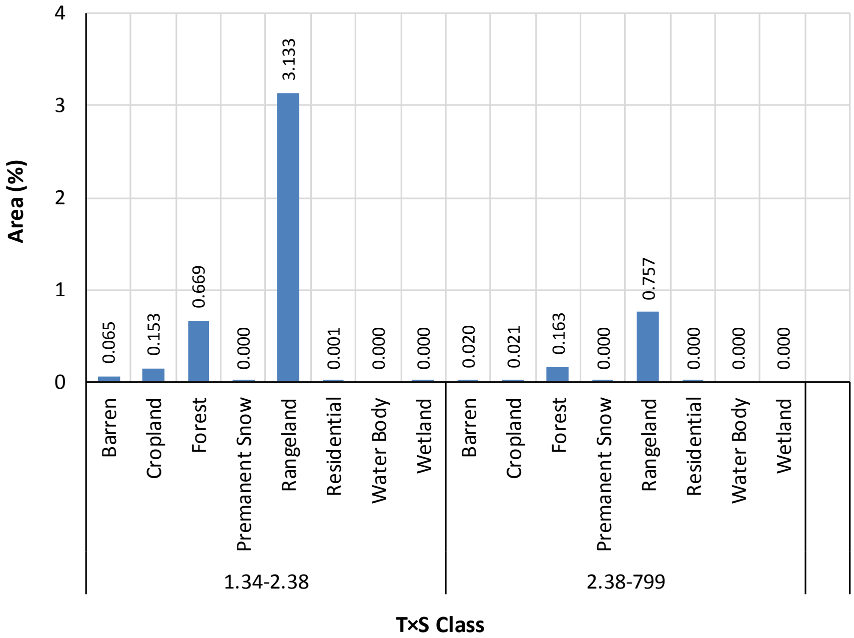

Figure 6. Erosion critical areas (%) for T×S > 1.34 in different land uses of the Iranian part of the Caspian Sea Basin

According to Figure 6, rangeland has the highest values of terrain influence multiplied by soil erodibility in the study watershed. In other words, 3.89 % of the rangelands can be considered as erosion critical areas and therefore, any vegetation removal and land use change especially to agricultural lands in these areas can lead to accelerated soil erosion rates.

The results showed that by considering the high soil erodibility and terrain influence factors, the highest erosion potential value as 7.99 located in the middle parts of the basin, where the highest slope gradients have relatively high soil erodibility values too. These areas are mainly located in the south slopes of the Alborz mountains. These results confirmed the findings reported by Mohammadi *et al*. (2021). As a result, the lack of vegetation cover as well as heavy rainfalls will cause more severe erosion in these areas, compared to the other parts of the basin. It is highly recommended to study the vegetation cover in the study area and also to compare soil erosion observations and estimations using other soil erosion models to increase the accuracy of the results. Confirming the findings reported by Mostafazadeh *et al*. (2017) and Belayneh *et al*. (2019), this conclusion most be used by natural resources managers and design-makers to avoid any land use change specially from rangeland to cultivation in the erosion critical areas.

CONCLUSION

According to the study results, the mean values of soil erodibility (S) and terrain influence (T) in the Iranian part of the Caspian Sea Basin were 0.039 (t ha hr ha^{-1} MJ^{-1} mm^{-1}) and 7.68, respectively. Soil erodibility was found to be moderate and high in most parts of the study area, (especially in rangelands, forests and croplands). Soil erosion potential map based on multiplying two main factors of soil erodibility and terrain showed the critical areas. It is highly recommended to study and focus more on these critical areas to locate urgent crop and grazing management programs and soil conservation measures. In other word, the critical areas should have more vegetation cover especially during seasons with erosive and high intensity rainfalls.

ACKNOWLEDGMENTS

This research was conducted as a part of doctoral dissertation of Khadijeh Haji and with the financial support of Tarbiat Modares University, Iran. Authors would like to thank Shahin Mohammadi for his great helps in preparing land use map of the study area.

REFERENCES

Aburas, M.M., Habel, A.Y., Alferjani, A.S., Yous, M.S. (2020). Assessment of soil erodibility and erosion risk of some semiarid slopes of Libya. Quality Assurance Center of Eastern Province Quality Assurance Journal for Academic Researches: 1-13.

Alamdari, P., Nematollahi, O., Alemrajabi, A.A. (2013). Solar energy potentials in Iran: A review. Renewable and Sustainable Energy Reviews 21: 778-788.

Behzadfar, M., Djurovic, N., Simunic, I., Filipovic, M. and Spalevic, V. (2014). Calculation of soil erosion intensity in the S1-6 Watershed of the Shirindareh River Basin, Iran; p. 207-213. Conference: Challenges in Modern Agricultural Production, Dec 2014, Skopje, N.Macedonia. Book of Proceedings, p. 273.

Belayneh, M., Yirgu, T., Tsegaye, D. (2019). Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques. Environmental Systems Research 8(20): 1-17.

Billi, P., Spalevic, V. (2022). Suspended sediment yield in Italian rivers. Catena 212(2022):106119. Doi: 10.1016/j.catena.2022.106119

Biswas, S.S., Pani, P. (2015). Estimation of soil erosion using RUSLE and GIS techniques: a case study of Barakar River basin, Jharkhand, India. Model. Earth Systems and Environment 1-42.

Chalise, D., Kumar, L., Shriwastav, C.P., Lamichhane, S. (2018). Spatial assessment of soil erosion in a hilly watershed of Western Nepal. Environmental Earth Sciences 77 (19): 685.

Chalise, D., Kumar, L., Spalevic, V., Skataric, G. (2019). Estimation of Sediment Yield and Maximum Outflow Using the IntErO model in the Sarada River Basin of Nepal. Water 11: 952, https://doi.org/10.3390/w11050952.

Chalise, D., Lumar, L. (2020). Land use change affects water erosion in the Nepal Himalayas. PLoS ONE 15(4).

Chavoshi, S., Sulaiman, W.N.A., Saghafian, B., Sulaiman, M.N.B., Abd Mana, L. (2013). Flood prediction in southern strip of Caspian Sea Watershed. Water Resources and The Regime of Water Bodies 40(6): 593-605.

Costea, A., Bilasco, S., Irimus, I.-A., Rosca, S., Vescan, I., Fodorean, I., Sestras, P. (2022). Evaluation of the Risk Induced by Soil Erosion on Land Use. Case Study: Guruslau Depression. Sustainability 2022, 14, 652.

Desmet, P.J.J., Govers, G. (1996). A GIS procedure for automatically calculating the USLE LS factor on topographically complex landscape units. Journal of Soil and Water Conservation, 51(5): 427-433.

Dutal, H., Reis, M. (2020). Determining the effects of land use on soil erodibility in the Mediterranean highland regions of Turkey: a case study of the Korsulu stream watershed. Environmental Monitoring and Assessment 192 (192): 1-15.

Fagbohun, B.J., Anifowose, A.Y.B., Odeyemi, C., Aladejana, O.O., Aladeboyeje, A.I. (2016). GIS-based estimation of soil erosion rates and identification of critical areas in Anambra sub-basin, Nigeria. Modeling Earth Systems and Environment 2(159): 1-10.

Friedl, MA., Sulla-Menashe, D., Tan, B., Schneider, A., Ramankutty, N. *et al*. (2010). MODIS Collection 5 global land cover: Algorithm refinements and characterization of new datasets. Remote Sens Environ, 114(1): 168-182.

Karami, E., Ghorbani Dashtaki, S., Khalilimoghadam, B. (2018). Effects of land management on soil erodibility-A case study in part of Zayandeh-Rood watershed. Journal of Agricultural Engineering, 40(2): 105-119.

Karydas, C.G., Panagos, P. (2018). The G2 erosion model: An algorithm for month-time step assessments. Environmental Research 161: 256-267.

Khaledi Darvishan, A., Mohammadi, M., Skataric, G., Popovic, S., Behzadfar, M., Rodolfo Ribeiro Sakuno, N., Luiz Mincato, R., Spalevic, V. (2019). Assessment of soil erosion, sediment yield and maximum outflow, using IntErO model (Case study: S8-Inta Shirindarreh watershed, Iran). Agriculture and Forestry, 65 (4), 203-210

Kulikov, M., Schickhoff, U., Gröngröft, A., Borchardt, P. (2017). Modelling soil erodibility in mountain rangelands of South-Western Kyrgyzstan. Pedosphere, https://doi. org/10.1016/S1002-0160(17)60402-8.

Kuriqi, A., Hysa, A. (2021). Multidimensional Aspects of Floods: Nature-Based Mitigation Measures from Basin to River Reach Scale. In: The Handbook of Environmental Chemistry. Springer, Berlin, Heidelberg. https://doi.org/10.1007/698_2021_773

Lense, G.H.E., Moreira, R.S., Parreiras, T.C., Silva, L.F.P, M., Teodoro, A.E.M., Mincato, R.L. (2020). Simulating the effect of permanent preservation areas on soil erosion rates. Cerne, 26 (2), 193-201.

Lense, G.H.E., Parreiras, T.C., Spalevic, V., Avanzi, J.C., & Mincato, R.L. (2021). Soil losses in the State of Rondônia, Brazil. Ciência Rural, 51(5), 1-10. e20200460. Epub March 08, 2021. https://doi.org/10.1590/0103-8478cr20200460

Lima Soares, D., Polivanov, H., Velloso Barroso, E., Goretti da Motta, L.M., Camacho de Souza, C. (2018). Soil erodibility on cutting slopes of Unpaved roads. Anuario do Instituto de Geociencias 41(1): 179-193.

Mohammadi, S., Balouei, F., Haji, Kh., Khaledi Darvishan, A., Karydas, C.G. (2021). Country-scale spatio-temporal monitoring of soil erosion in Iran using the G2 model. International Journal of Digital Earth, 14(8): 1019-1039.

Moore, I.D., Burch, G.J. (1986). Physical basis of the length-slope factor in the Universal Soil Loss Equation. Soil Science Society of America Journal 50: 1294-1298.

Mostafazadeh, R., Haji, Kh., Esmali-Ouri, A., Nazarnejad, H. (2017). Prioritization the critical sub-watersheds based on soil erosion and sediment using watershed erosion response model (WERM) and Morphometric Analysis (Case study: Rozechai Watershed, West Azerbaijan Province). Journal of Watershed Management Research 8(16): 142-156 (in Persian).

Ouallali, A,, Aassoumi, H., Moukhchane, M., Moumou, A., Houssni, M., Spalevic, V., Keesstra, S. (2020). Sediment mobilization study on Cretaceous, Tertiary and Quaternary lithological formations of an external Rif catchment, Morocco, Hydrological Sciences Journal, 65(9), 1568-1582.

Panagos, P., Meusburger, K., Alewell, C., Montanarella, L. (2012). Soil erodibility estimation using LUCAS point survey data of Europe. Environmental Modelling Software 30: 143-145.

Panagos, P., Meusburger, K., Ballabio, C., Borrelli, P., Alewell, C. (2014). Soil erodibility in Europe: a high- resolution dataset based on LUCAS. Science of the Total Environment 479: 189-200.

Parmar, S., Sharma, S.K. (2020). Estimation of soil loss and soil erodibility for different crops, nutrient managements and soil series. International Journal of Pure Applied Bioscience 8(1): 204-212. doi: http://dx.doi.org/10.18782/2582-2845.7984

Reis, M., Aladag, I.A., Bolat, N., Dutal, H. (2017). Using Geoweep model to determine sediment yield and runoff in the Keklik watershed in Kahramanmaras Turkey. Sumar. List 141: 563-569.

Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K., Yoder, D.C. (1997). Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE). In: Agriculture Handbook, U.S. Department of Agriculture, 703: 404 p.

Renschler, C.S., Mannaerts, C., Diekkrüger, B. (1999). Evaluating spatial and temporal variability in soil erosion risk-rainfall erosivity and soil loss ratios in Andalusia, Spain. Catena 34: 209-225.

Rosas, M.A., Gutierrez, R.R. (2019). Assessing soil erosion risk at national scale in developing countries: The technical challenges, a proposed methodology, and a case history. Science of the Total Environment 703: 135474.

Sadeghi, S.H.R. (2009). An overview on sediment problems and management in Iran. Sediment Problems and Sediment Management in Asian River Basins, In: Proceedings of the ICCE Workshop, Hyderabad, India, Sep. IAHS Pub 349:14-20.

Solaimani, K., Modallaldoust, S., Lotfi, S. (2009). Investigation of land use changes on soil erosion process using geographical information system. International Journal of Environmental Science and Technology, 6(3): 415-424.

Spalevic, V., Barovic, G., Vujacic, D., Curovic, M. Behzadfar, M., Djurovic, N., Dudic, B., Billi, P. (2020). The Impact of Land Use Changes on Soil Erosion in the River Basin of Miocki Potok, Montenegro. Water, 2020, 12, 2973.

Spalevic, V., Djurovic, N., Mijovic, S., Vukelic-Sutoska, M., Curovic, M. (2013). Soil Erosion Intensity and Runoff on the Djuricka River Basin (North of Montenegro). Malaysian Journal of Soil Science. 17, 49-68.

Spalevic, V., Zejak, D., Curovic, M., Glisic, I., Radovic, A. (2021): Analysis of the impact of fruit growing development on the intensity of soil erosion and runoff: Case study of Krusevo, Bijelo Polje, Montenegro. Agriculture and Forestry, 67 (2): 37-51

Stefanidis, P., & Stefanidis, S. (2012). Reservoir sedimentation and mitigation measures. Lakes & Reservoirs: Research & Management, 17(2): 113-117.

Stefanidis, S., Alexandridis, V., Ghosal, K. (2022). Assessment of Water-Induced Soil Erosion as a Threat to Natura 2000 Protected Areas in Crete Island, Greece. Sustainability 14(5): 2738.

Stefanidis, S., Chatzichristaki, C., Stefanidis, P. (2021). An ArcGIS toolbox for estimation and mapping soil erosion. J. Environ. Prot. Ecol, 22, 689-696.

Sulla-Menashe D, Friedl MA (2018). User guide to collection 6 MODIS land cover (MCD12Q1 and MCD12C1) Product. 1-18.

Talebikhiavi, H., Zabihi, M., Mostafazadeh, R. (2017). Effects of land-use management scenarios on soil erosion rate using GIS and USLE model in Yamchi dam watershed, Ardabil. Journal of Water and Soil Science (Science and Technology of Agriculture and Natural Resources), 21(2): 221-234 (in Persian).

Taleshian Jeloudar, F., Ghajar Sepanlou, M., Emad, S.M. (2018). Impact of land use change on soil erodibility. Global Journal of Environmental Science and Management, 4(1): 59-70.

Tavares, A.S., Spalevic, V., Avanzi, J.C., Nogueira, D.A., Silva, M.L.N., Mincato,R.L. (2019). Modeling of water erosion by the erosion potential method in a pilot subbasin in southern Minas Gerais. Semina: Ciencias Agrarias, 40(2), 555-572.

Vaezi, A.R., Hasanzadeh, H., Cerda, A, (2016). Developing an erodibility triangle for soil textures in semi-arid regions, NW Iran. Catena, 142: 221-232.

Wang, H., Zhang, G. (2021). Temporal variation in soil erodibility indices for five typical land use types on the Loess Plateau of China. Geoderma 381: 114695.