Regional analysis of suspended sediment load in Haraz-Neka Drainage Basin, Iran

Analyse régionale de la charge en sédiments en suspension dans le bassin hydrographique de Haraz-Neka, Iran

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RÉSUMÉ

La prévision de la charge sédimentaire en suspension est essentielle pour une gestion durable de la qualité et des services des rivières. L'analyse régionale des sédiments en suspension est une méthode importante pour estimer la charge sédimentaire dans les bassins de drainage non jaugés ou les jauges avec des données mesurées à court terme. L'objectif de cette étude était de déterminer la relation entre les sédiments spécifiques en suspension et les caractéristiques physiques des bassins versants sélectionnés dans le bassin versant Haraz-Neka, afin de présenter un modèle régional pour estimer la charge spécifique en sédiments en suspension dans le bassin versant. Dans cette optique, 23 jauges ont été sélectionnées, et la charge spécifique annuelle moyenne de sédiments en suspension a été déterminée comme variable dépendante et 20 variables physiques des bassins versants ont été calculées comme variables indépendantes. L'analyse hiérarchique agglomérative a été utilisée pour diviser les 23 sous-bassins associés aux jauges en deux groupes homogènes. La charge spécifique de sédiments en suspension avec différentes périodes de retour a été calculée en utilisant la distribution de type Log-Pearson-III comme meilleure fonction de distribution de probabilité régionale dans deux zones homogènes. Enfin, la méthode de régression multiple par étapes a été appliquée pour définir la relation entre la charge sédimentaire spécifique en suspension pour les différentes périodes de retour et les caractéristiques physiques des bassins versants. Le résultat des modèles a montré un coefficient de détermination pour les périodes de retour de 10 et 25 ans de 76% et 80% dans le cluster homogène 1, et de 87% et 86% dans le cluster homogène 2, respectivement.

ABSTRACT

Prediction of suspended sediment load is essential for a sustainable management of river quality and services. Regional analysis of suspended sediment is an important method to estimate the sediment load in ungauged drainage basins or gauges with short-term measured data. The aim of this study was to determine the relationship between specific suspended sediment and the physical characteristics of selected catchments in the Haraz-Neka Drainage Basin, to present a regional model to estimate specific suspended sediment load in the drainage basin. In view of this, 23 gauges were selected, and the average annual specific suspended sediment load was determined as a dependent variable and 20 physical variables of the catchments were calculated as independent variables. Hierarchical agglomerative cluster analysis was used to divide the 23 associated sub-basins to the gauges into two homogeneous clusters. Specific suspended sediment load with different return periods were calculated using Log-Pearson type-III distribution as the best regional probability distribution function in two homogeneous areas. Finally, stepwise multiple regression method applied to define the relationship between the specific suspended sediment load in the different return periods and physical characteristics of the catchments. The result of the models exhibited coefficient of determination for 10 and 25-year return periods was 76% and 80% in the homogeneous cluster 1, and 87% and 86% in the homogeneous cluster 2, respectively.

KEYWORDS

Haraz-Neka Drainage Basin, multiple regression, regional analysis, specific suspended sediment, sub-basin physical characteristics.

1 INTRODUCTION

Suspended sediment load is defined as the total sediment load discharged by a catchment or the amount of sediment delivered to a point in the river network over a time period. It is controlled mainly by hydrometeorology, topography, geology and land use/land cover (Heng and Suetsugi, 2014). Knowledge about suspended sediment load is important for water quality management, ecological needs, ecosystem services and wastewater treatment. Thus, prediction of suspended sediment load is essential for a sustainable management of river quality and services. Regional analysis of suspended sediment is an important method to estimate the sediment load in ungauged drainage basins or gauges with short-term measured data. Regional models are established by associating independent variables (catchment descriptors) as the predictors and therefore allow solely a point value prediction (the mean annual sediment yield). In this view, the objective of this research is to develop a regional SPR (sediment production rate) model for use in ungauged areas of the Haraz-Neka Drainage Basin.

2 MATERIALS AND METHODS

2. 1 Study area

Haraz-Neka Drainage Basin is located in the southwest of the Caspian Sea in Iran within the boundaries of Mazandaran, Golestan and part of Tehran Provinces (Fig.1). The area of Haraz-Neka Drainage Basin is 18644 Km^2 which includes 39.28%, 31.98%, 27.12% and 1.62% for forest, agriculture, rangelands and residential urban area, respectively. The drainage basin has variable lithological characteristics, with outcrops of Palaeozoic to Quaternary formations. The minimum and maximum height of the study basin is -74 and 5609 m (m.a.s.l.). The climate of the basin is generally humid to semi-humid Mediterranean, while in the eastern parts is semi-arid to arid. The main river of the area is the Haraz River which originates in the Alborz Mountains and, after junction with some main tributaries, flows into the Caspian Sea.

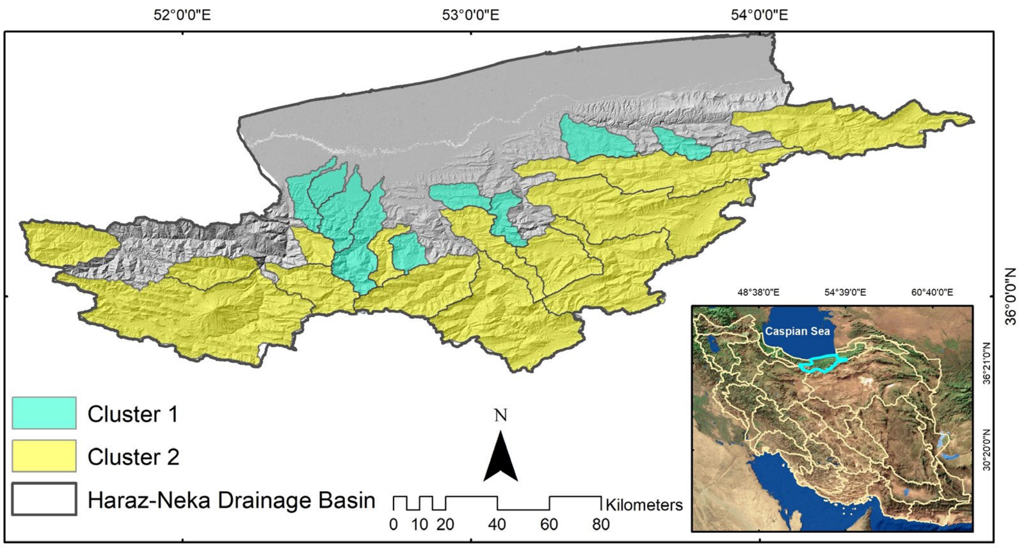

Fig. 1 Geographic location of the Haraz-Neka Drainage Basin, Iran; and homogeneous clusters 1 and 2.

2.2 Methods

Suspended sediment load data were obtained from the archives of the Water Resources Research Organization, Iran for 23 stations in the study area. Selected river gauges with a continuous 25-year record (1991–2016) were used in this study. Then, for each catchment drainage area, perimeter, mean slope gradient, mean, maximum and minimum elevation, main stream length, drainage density, length and width of rectangle-equivalent, circularity ratio, time of concentration, mean annual precipitation, forest, agriculteur, rangeland and urban fraction per cent, and percentage of geological formations with high, medium, and low infiltration capacity were determined by GIS software. In order to calculate specific suspended sediment, nine probability distributions including the normal, log-normal, gamma, Pearson type-III, log-Pearson type-III, Weibull, Gumbel Max and Gumbel Min distributions were evaluated to determine which distribution most appropriately fit the specific suspended sediment. The Kolmogorov–Smirnov test and ranking method were used to determine the best fitting distributions in the homogeneous area using EasyFit 5.5 (Nosrati et al., 2015). In the next step, hierarchical agglomerative cluster analysis was used to divide the 23 gauging stations into homogeneous regions based on the similarity of the 20 physical characteristics (including physiographic, climatic, geological and land use) of the sub-basins. Finally, the physical characteristics of each sub-basin in the homogeneous regions as independent variables and the specific suspended sediment load in different return periods as depend variable were used in stepwise multivariate regression analyses to develop the best equations (models) able to predict specific suspended sediment load. The regression statistics including adjusted R^2 and the smallest p-value of the F-test were used to provide the best subset selection of predictors by examining all possible regressions.

3 RESULTS AND DISCUSSION

The physical charactersitics and specific suspended sediment load were calculated for all sub-basins and two homogeneous clusters were determined based on physical charactersitics and hierarchical agglomerative cluster analysis. In this regards, Shirgah, Rig Cheshmeh, Ablu, Glord, Koshtargah, Diva, Boliran, Galougah, and Pashakola sub-basins were located in the homogenous cluster 1 and, Varand, Soleyman Tange, Sefidchah, Bade Cheshmeh, Garmrood, Ghable Cheshmeh, Panjab, Balad, Ghoran Talar, Kiakola, Koreh Sang, Kordkhil, and Lajim sub-basins were located in the homogenous cluster 2. The first homogenous cluster include low extension area, low mean elevation and low average slope and the second homogenous cluster include high extension area, high mean elevation and high average slope of basin. The stepwise regression analysis was applied to prepare mathematical models for two homogenous clusters in Haraz-Nneka Drainage Basin by using physical characteristics and specific suspended sediment load in different returen periods (log-Pearson type-III (LPIII) distribution). The results of modeling have been summarized in the Tables 1. According to Heng and Suetsugi (2014) and Nosrati et al., (2015), the catchment area is the most important variable in regional modelling. This study showed that the sub-basins areas of cluster 1 are approximately same and low extend so the mean annual precipitation in homogenous cluster 1 is main affecting factor in the model but the sub-basins areas of cluster 2 are different therefore, the factor of area and perimeter in homogenous cluster 2 have important controls of specific suspended sediment load.

Table1 Best set of prediction variables for specific mean suspended sediment in the two homogeneous regions

Homogeneous region	Return period	R^2	Adjusted R^2	F	p-value	Model
Cluster 1	10	0.76	0.73	22.37	0.002	Y = -198.534+.541(Rainfall)
	25	0.80	0.78	28.65	0.001	Y= -759.340+2.029 (Rainfall)
Cluster 2	10	0.87	0.86	82.51	0.000	Y=-137.948+2.592(Area)
	25	0.86	0.84	34.42	0.000	Y=1317.356+10.248(Area)-27.499(Perimeter)

4 CONCLUSION

In this study, the regional specific suspended sediment load was examined for the Haraz-Neka Drainage Basin, Iran. Analyses were based on a data set suspended sediment load for 23 gauges measured over a 25-year standard observation period. The cluster analysis obtained two clusters for all gauges. Also, the specific suspended sediment was determined using log-Pearson type-III (LPIII) distribution, which was selected in a comparative analysis as the best regional probability distribution function in homogeneous regions 1 and 2. The result of the regression equations exhibited coefficient of determination of 76% (10-year return period) and 80% (25-year return period) in the homogeneous cluster 1, and 87% (10-year return period) and 86% (25-year return period) in the homogeneous cluster 2. This study showed that mean annual precipitation in homogenous cluster 1, and area and perimeter in homogenous cluster 2 have important controls of specific suspended sediment in the study area. Taken together, the regional equations are expected to provide estimates of specific suspended sediment values for basins in areas of similar geomorphology, geology and climate.

LIST OF REFERENCES

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