J. Agr. Sci. Tech. (2012) Vol. 14: 1637-1646

Effects of Sand Mining on Suspended Sediment Particle Size Distribution in Kojour Forest River, Iran

S. H. R. Sadeghi[1*], and M. Kiani Harchegani[1]

ABSTRACT

Soil erosion causes sediments to be detached from their source materials and transported as suspended particles. The present study was conducted to evaluate the effects of sand exploitation on the distribution of suspended sediments in the Educational and Research Forest Watershed of Tarbiat Modares University, which comprises approximately 50,000 ha. Fifty-one water samples were collected before and after sand mining between November 2007 and June 2008. The settling rates of the primary particles of suspended sediments were then analyzed based on the principle of sedimentation described by Stokes' law and using the modified pipette technique. Analyses of the samples indicated that the Suspended Sediment Particle Size Distribution (SSPSD) was significantly affected by sand mining. Specifically, an independent samples T-test demonstrated that the mean contents of sand, silt and SSC during and after sand mining differed significantly (P< 0.01), with respective values of 74.19±13.4 and 9.75±13.8, 81.77±4.5 and 2.96±2.7% and, 7.66±7.7 and 0.34±0.3 g l^{-1} being observed. Additionally, no significant difference was found between data sets collected before and during sand mining for hydrologic and SSPSD characteristics at 1%, which clearly proved consequent effects of sand mining on SSPSD.

Keywords: Kojour watershed, Particle size distribution, Sand mining, Suspended sediment concentration.

INTRODUCTION

Human activities have long been recognized as external factors affecting soil evolution and soil erosion (Montagne *et al.*, 2008; Naik *et al.*, 2011). Soil erosion and sedimentation cause on-site degradation of the natural resource base, as well as off-site problems such as downstream sediment deposition in fields, floodplains and water bodies, which can lead to water pollution, eutrophication and reservoir siltation (Zapata, 2003). Therefore, knowledge of the processes involved in the generation, transport and deposition of such sediments, and of the associated changes in the particle size characteristics of sediments during erosion, is clearly of fundamental importance to understand the fate of chemicals (Slattery and Burt, 1997; Walling and Moorehead, 2004). Without detailed measurements of sediment transport in catchments, the various erosional mechanisms responsible for sediment mobilization cannot be identified (Walling and Moorehead, 2004). Accordingly, knowledge of the particle sizes and the size distribution of suspended sediments is necessary for the realization of transport, sedimentation and control process (Jillavenkatesa *et al.*, 2001).

Knowledge of particle size distribution is critical for understanding particulate matter transport and fate and pollutant partitioning and distribution (Walling and Woodward, 1993; Kim and Sansalone, 2008). Walling

[1] Department of Watershed Management Engineering, Faculty of Natural Resources, Tarbiat Modares University, Noor, Islamic Republic of Iran.
[*] Corresponding author; e-mail: sadeghi@modares.ac.ir

and Moorehead (2004) reported that investigations of the dynamics of sediment movement through a river system must also take into account the potential contrast between the absolute particle size distribution, i.e. the primary mineral particles, and effective particle size distribution, which represents composite particles, of suspended sediments in response to aggregation.

Geomorphologists and hydrologists have frequently studied suspended sediments in rivers because they can provide important information regarding the processes of erosion and deposition. The particle size distribution of sediments can be analyzed using different methods such as the laser diffraction method, gamma-ray attenuation, X-ray diffractometry, hydrometery, and dielectric, pipette and sieving methods (Liu *et al*., 1966; Indorante *et al*., 1990; Beuselink *et al*., 1998; Krishnappan, 2000; Naime *et al*., 2001; Gasparatto *et al*., 2003; Poizot *et al*., 2008). However, few studies have been conducted to evaluate the distribution of suspended sediment particles. The results of a study conducted in the Exe basin (Williams *et al*., 2007) indicated that, even in rivers with relatively low solute concentrations, almost an order of magnitude difference existed between the median particle size associated with the absolute and effective grain size distributions. In addition, Walling *et al.* (2000) and Williams *et al.* (2007) demonstrated that the particle size characteristics of suspended sediments were of fundamental importance in understanding their role in a variety of environmental processes such as contaminant transportation. The impact of marine sand mining operations in a complex coastal environment was also successfully modeled by Kim and Lim (2009) in Korea. The resulting depositional patterns suggest that only the coarser size classes (500 and 250 mm) particles remain close to the mined site, while finer size classes are widely dispersed. Haritashya *et al.* (2010) also presented temporal variations in the particle size characteristics of suspended sediments transported in meltwater from the Gangotri Glacier, central Himalaya. The results of their study showed no relationships between discharge and particle size. Several other studies (De Boer, 1997; Walling, 1997; Neal *et al*., 1998; Zhang *et al*., 2006; Sadeghi *et al*., 2008) have demonstrated that anthropogenic activities increased the production and transportation of suspended sediments via impacts on fluvial systems and changes in the properties of the suspended sediments.

Despite the importance of suspended sediment particle size distribution (SSPSD) in transportation and deposition process and control, limited attention has been made to particle size distribution studies. Therefore, understanding of the role that humans play on changes in SSPSD is consequently very limited. The goal of the present study was to analyze SSPSD in the Kojour River during 2007-2008 and then investigate the effects of sand mining on the SSPSD. It was then hypothesized that the sand mining activities have a significant effect on the SSPSD.

MATERIALS AND METHODS

Site Characterization

The Educational and Research Forest Watershed of Tarbiat Modares University (Kojour Forest Watershed) is part of basin 46 of central Alborz, which is located in the southeastern portion of Nowshahr, northern Iran. It was selected for the present study due to easy accessibility, available research backgrounds and condition controllability. The area of the watershed is 50,000 ha and it lies between 36° 13″ 30′ and 36° 33″ 0′ N latitude and 51° 35″ 0′ and 51° 50″ 30′ E longitude. Elevation ranges from some 150 to 2,650 m above mean sea level. More than 90% of geology formations belong to second geological era. The watershed is deeply incised with a dominant hillslope gradient of 25–60%. Soil in the watershed is brown forest soil, which is classified as Pseudogley with loamy sand texture, and its organic matter content is about 0.089 g g^{-1} (Figure 1). The average maximum and minimum temperatures and mean annual precipitation (1977 to 2007) are 19.9; 13°C, and 1,287.8 mm, respectively. The study area has a humid and semi-humid climate in the north and south, respectively. The watershed is primarily covered by forest with an average stand density of >75% (Sadeghi and Saeidi, 2010).

Research Methodology

To conduct the present study, suspended sediment samples were collected from the left bank of the Kojour River (Figure 1) semiweekly from November 2007 to June 2008. The study period consisted of two sub-periods of natural and sand mining conditions. The sand mining was made intensively by using heavy machineries from the main channel bed, almost 1km far upstream, lasted for some 1.5 months and resulted in concentrated disturbances in channel morphology and flow system. Suspended sediment data were obtained through water sampling using plastic vessels with a volume of 2000 ml following previously described depth-integrating procedures (Rovira and Batalla, 2006; Edwards and Glysson, 1999). Prior to sampling, all plastic vessels were cleaned with diluted nitrate detergent (Singh *et al*., 2005). Samples with a volume of 1,000 ml of some 2,000 ml samples collected above were immediately analyzed at the research laboratory of Tarbiat Modares University for SSPSD analysis. The dried suspended sediments were then obtained through decantation (Putjaroon and Pongboon, 1987) followed by evacuation of the upper pure water after two days, oven drying of the remaining concentrated sediment for 24 hours at 105°C (Sadeghi *et al*., 2006) and weighing of the net sediment using a scale with an accuracy of 0.0001 g.

The sediment samples were then analyzed based on Stokes' law (Naime *et al*., 2001), given in Equation (1), using a modified version of the pipette method (Indorante *et al*., 1990). The time for pipetting t (s) and height of pipette h (m) determine when and where the attenuation measurements should be made to calculate the diameter (d) of the

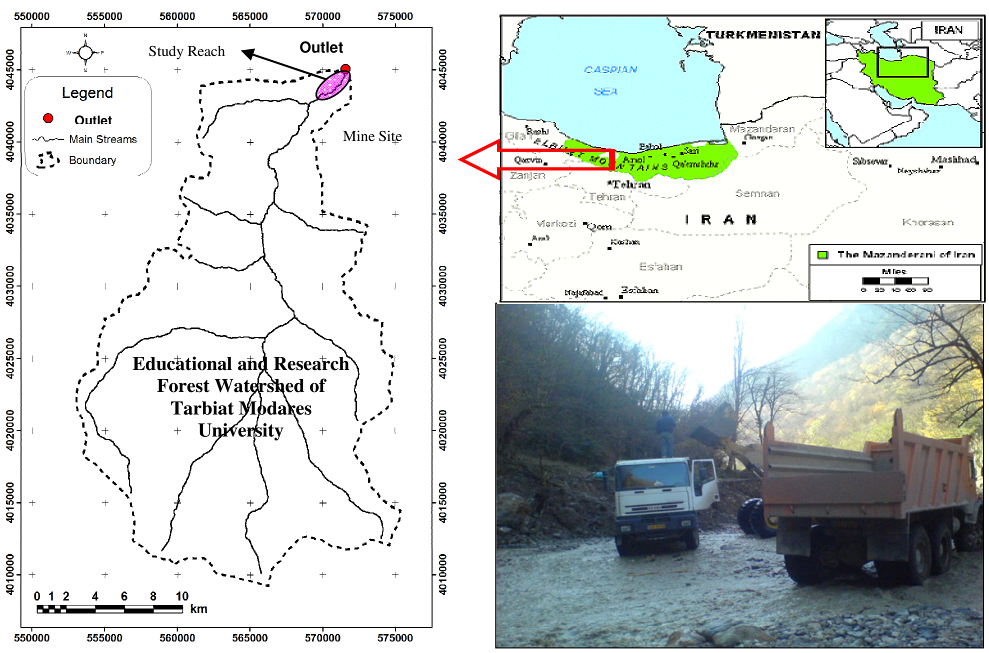

Figure 1. Location of the study watershed, reach and the sediment sampling site.

particles that correspond to the concentration:

$$t = \frac{18h\eta}{d^2 g(D_P - D_W)} \quad (1)$$

where η (kg m^{-1} s^{-1}) is the water dynamic viscosity, g (m s^{-2}) is the acceleration of gravity in a complete analysis, and D_w and D_p (kg m^{-3}) are the densities of water and soil particles, respectively (Naime *et al*., 2001; Indorante *et al*., 1990). Next, the sediment particles were classified according to their size as > 63 µm, from 2 to 63 µm and < 2 µm for sand, silt and clay, respectively (Walling, 1988; Beuselink *et al*., 1998; Walling *et al*., 2000). To conduct the particle size distribution analysis, different pre-treatments were made. To accomplish this, suspended sediments were placed in a 50 ml centrifuge tube, after which 10 ml of deionized water and 1.0 ml of 1.0 mol Na acetate (pH= 5.0) were added to the samples. The samples were then centrifuged for 15 min at 1,500 rpm until the supernatant was cleared. Next, the samples were decanted and washed two more times with 50 ml of deionized water. For suspended sediments containing greater than 3.5% organic matter, after removal of the carbonates, 10 ml of water and 5 ml of H_2O_2 were added to the suspension (Hardy and Cornu, 2006). In addition, solutions of 0.3 mol sodium citrate and 84 gl^{-1} sodium bicarbonate were added to the samples to remove the iron oxides. Next, 20 ml aliquots of the H_2O_2 treated samples were shaken by a shaker for 30 minutes to disperse the soil, after which 0.40 g of sodium dithionite ($Na_2S_2O_4$) was added. The samples were then placed in a water bath at 80^{o}C and stirred intermittently for 20 minutes. Next, the samples were removed, and 1.5 ml of a 10% NaCl solution was added, after which the samples were centrifuged and decanted. If a sample was brownish in color, the experiment was repeated using sodium citrate-sodium bicarbonate. If the sample was gleyed (gray), it was treated with 10% NaCl and then rinsed twice with deionized water. The prepared samples were finally subjected to further pre-treatments composed of the addition of 40 ml of sodium hexametaphosphate solution and subsequent incubation on a reciprocating horizontal shaker for sixteen hours (Chaudhari *et al*., 2008). After 16 hours of shaking, the centrifuge tubes were shaken by hand to disperse the samples, after which they were allowed to settle for the required time according to laboratory temperature and pre-defined conditions (Indorante *et al*., 1990). The time began once settling was initiated. Next, a 2.5 ml aliquot of the solution was dispersed, placed in a pre-weighed tin and then dried in a drying oven. The weights of the primary particles of sand, silt and clay were then calculated based on the following relationships (Indorante *et al*., 1990):

Sand % = 100-[((((Dry weight-Tin weight)-Blank)×40/2.5)/5)×100] (2)

Clay %= ((((Dry weight-Tin weight)-Blank)×40/2.5)/5)×100 (3)

Silt %= (100-%Sand)-%Clay (4)

The entire descriptive properties of the sediment samples were then calculated using the GRADISTAT software (Blott and Pye, 2001, Khaledi Darvishan *et al.,* 2008) available on the net. The method was classically applied using the graphical method proposed by Folk and Ward (1957) based on moments analyses. The sand mining effects on the SSPSD in the Kojour River were also assessed by an independent sample t-Test conducted using the SPSS13.5 software package to compare data sets obtained before, during and after sand mining. The mode, median, mean, sorting, skewness and kurtosis of the sediment samples were used to evaluate the effects of sand mining on the SSPSD since they are important in defining the trends (Blott and Pye, 2001).

RESULTS AND DISCUSSION

The suspended sediment samples used in this study were collected from the left bank of the Kojour River. The analyses of SSPSD were made using the modified pipette method for 51 collected samples. The descriptive statistics of the data collected during the study period are summarized in Table 1. The results of the independent samples t-Test are shown in Table 2. The variations in the Suspended Sediment Concentration (SSC) and the associated sand, silt and clay contents before, during and after sand mining are shown in Figure 2.

The results shown in Figure 2 and Table 1 revealed a drastic variation in the particle size composition of the suspended sediments (sand ranged from 47.20 to 89.95% and silt ranged from 0.13 to 38.85%) among study periods. However, there were no large variations in the clay content observed (average, 15.22~16.05%). As shown in Tables 1 and 2, the suspended sediments transported by the study river were dominated by coarse grained sediments that increased in size with increased SSC. The result suggests that the concentration of coarse particles is independent of discharge which leads to the conclusion that correlation between discharge and particle size is complex and depends on a combination of sediment availability and delivery restrictions, transport energy and erosive capabilities, and erosion and deposition. This is in agreement with previous studies carried out by Kim and Lim (2009) in Korea and Sadeghi and Saeidi (2010) in the same watershed in Iran. They found that the relationships between SSC–Q before, during and after of sand mining in the same study watershed i.e. Educational and Research Forest Watershed of Tarbiat Modares University, Iran was generally poor with correlation coefficient of 7–20%. These findings are in accordance with those of Slattery and Burt (1997) and Haritashya *et al.* (2010), who reported a negative relationship between discharge and particle size, but contrary to those of Walling *et al.* (2000), who reported a positive relationship between them. Results confirmed the dominance of silt-sized particles in the sediment load of the outflow stream in the study river during sand mining. This might be due to an active armoring by large sized bed sediments and also entrapping fine clay-sized particles in armored areas. The silt-sized particles decreased at the second peak of SSC because of their transportation during the first peak. As shown in Table 1, the mean and median particle size composition of the suspended sediments varied among periods. Specifically, the particle size decreased during sand mining, but no consistent trends existed among various characteristics of particle size (e.g. sorting, skewness and kurtosis). These findings are similar to those of Williams *et al.* (2007), who found that no consistent trends existed between water stage or SSC

Table 1. Descriptive statistics of some variables of sediment samples in Educational and Research Forest Watershed of Tarbiat Modares University.

Sediment size distribution characteristics	Periods of study with respect to sand mining								
	Before			During			After		
	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min
SSC (gl^{-1})	0.67	0.49±0.1	0.34	20.27	7.66±7.7	0.37	1.38	0.34±0.3	0.08
Discharge ($m^3 s^{-1}$)	1.04	0.77±0.25	0.39	1.03	0.62±0.25	0.38	1.56	0.50±0.41	0.04
Sand (%)	84.19	77.03±7.7	66.14	85.15	74.19±13.4	47.20	89.95	81.77±4.5	72.80
Silt (%)	11.97	6.08±4.3	2.68	38.85	9.75±13.8	0.96	12.03	2.96±2.7	0.13
Clay (%)	22.46	15.22±6.4	4.66	22.21	16.05±3.04	12.93	24.06	15.27±3.4	9.41
Mode (μm)	76.50	76.50±0.0	76.50	76.50	70.21±16.6	32.50	76.50	59.13±21.8	32.50
Median (μm)	265.20	215.03±36.6	162.00	243.21	197.78±55.2	87.72	262.20	229.12±35.8	191.30
Mean (μm)	265.20	198.08±54.5	128.30	243.21	189.30±41.2	135.50	262.20	211.42±35.8	130.70
Sorting (μm)	4.50	3.59±0.7	2.37	4.96	3.80±0.6	3.31	5.24	3.74±0.6	3.00
Skewness (μm)	-0.06	-0.23±0.1	-0.37	0.29	-0.19±0.2	-0.38	-0.19	-2.27±12.3	-76.06
Kurtosis (μm)	1.37	1.20±0.1	0.84	1.41	1.34±0.1	1.22	1.42	1.35±0.6	1.19
Number of samples		6			7			38	

Table 2. Results of applying independent samples t-Test for the comparison of SSPSD in the Kojour River.

Weight of particles (%)	*P*-values for pair data sets between two different study periods		
	Before and during sand mining	During and after sand mining	Before and after sand mining
Sand	0.660	0.007**	0.034*
Silt	0.550	0.006**	0.020*
Clay	0.760	0.570	0.976
SSC	0.044	0.000	0.284
Q	0.776	0.674	0.511

** and * represent significant levels at 1 and 5%, respectively.

and various characteristics of particle size during storm events in the Exe basin.

Analysis of the data provided in Table 2 using an independent samples t-Test revealed that there were no statistically significant differences ($P > 0.55$) in the particle contents in the periods before and during sand mining. These findings verified the persistent proportion of different suspended sediment particle sizes in the SSCs. However, there were statistically significant differences ($P < 0.007$) between the particle size compositions of the suspended sediments (sand and silt) during and after sand mining due to a drastic reduction in the SSC of approximately 22.6 fold. These changes were primarily associated with a respective increase and decrease in sand and silt contents. In addition, there were statistically significant differences ($P < 0.029$) in the particle size composition of suspended sediments (sand, silt and clay) before and after sand mining, which demonstrated that considerable variability in the particle size distribution occurred during sand mining. The lowest variation was observed in the clay content, which clearly verifies the changeability of

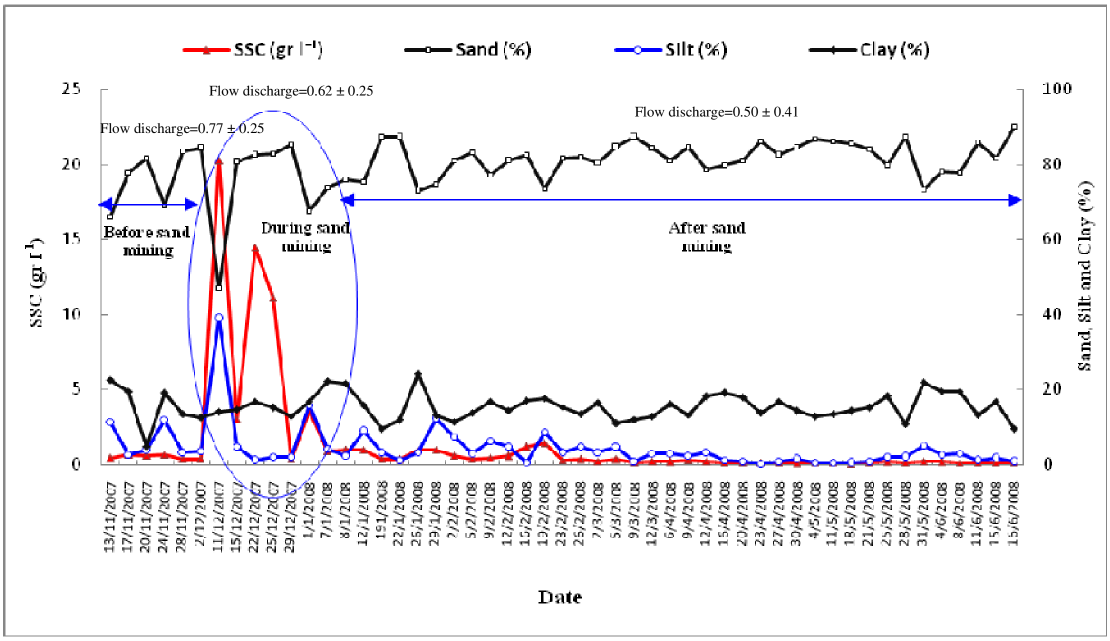

Figure 2. Variations of SSC, sand, silt and clay, and range and standard deviation of flow discharge before, during and after of sand mining in the Kojour River (Educational and Research Forest Watershed of Tarbiat Modares University), Iran.

clay content by the amount of sediment yielded from upland areas, as well as the ease of transport and armoring phenomenon in bed load rather than human intervention through sand mining. This agrees with Peters and Hulscher (2006) who verified changes in river morphology due to sand extraction in the Netherlands. Taken together, the results of this study demonstrate that anthropogenic activities such as sand mining have an effect on the natural behavior of fluvial systems, which is similar to the results of studies conducted by De Boer (1997), Walling (1997), Neal *et al*. (1998), Zhang *et al*. (2006) and Sadeghi *et al*. (2008) in different parts of the world with dissimilar levels of suspended sediment particles. Sand mining activities disturb natural governing conditions on the river fluvial system leading to changes in the transportability and consequent availability of bed/bank materials. It then continues until anthropogenic activities are ceased and the healing stage of the system is completed.

CONCLUSIONS

In this study, the effects of sand mining on the particle size distribution of suspended sediments through a river system in the Educational and Research Forest Watershed of Tarbiat Modares University (Kojour Forest watershed) were evaluated. Recently, there has been an increasing demand for sand mining and the current supply of sand is insufficient, particularly in developing countries owing to rapid infrastructural activities. Therefore, detailed studies evaluating fluvial systems are essential. Accordingly, this study was conducted to investigate the effects of sand mining on SSPSD in the Kojour River. To accomplish this, sediment samples were analyzed based on Stokes' law with the aid of the modified pipette method. The results of this study indicated that sand mining not only had changed the fluvial behavior of the study river as reported by many pervious studies but also had a significant effect on the particle size distribution of suspended sediments in the study area. Considerable variability was also observed in the particle size characteristics of suspended sediments in response to sand mining, with more variation being observed in the sand and silt contents. Although the predefined hypothesis has been proved during the present study, additional studies are required to enable development of a basic framework for balancing human needs with damage to the environment. There is also a need to know how long the impact of human interferences through sand mining would persist in a watershed.

ACKNOWLEDGEMENTS

The authors wish to thank Eng. S. Boor (Technical Assistant of Watershed Management Department Laboratory) at Tarbiat Modares University for his technical assistances in laboratory experiments. The authors are also indebted to Eng. P. Saeidi for her valuable help during field work. This research has also been partly supported by the Iran National Science Foundation (Project No. 12-10100012) whose valuable assistance is appreciated.

REFERENCES

1. Beuselinck، L., Govers، G., Poesen، J. and Degraer Froyen، G. 1998. Grain-size Analysis by Laser Diffractometry: Comparison with the Sieve-pipette Method. *Catena,* **32:** 193-208.
2. Blott, S. S. and Pye, K. 2001. Gradistat: A Grain Size Distribution and Statistics Package for the Analysis of Unconsolidated Sediment. *Earth. Surf. Proc. Land,* **26(11):** 1237-1248.
3. Chaudhari, S. K., Singh. R. and Kundu, D. K. 2008. Rapid Textural Analysis for Saline and Alkaline Soils with Different Physical and Chemical Properties. *Soil Sci. Soc. Am. J.,* **72**: 431-441.
4. De Boer, D. H. 1997. Changing Contribution of Suspended Sediment

Sources in Small Basins Resulting from European Settlement on the Canadian Prairies. *Earth. Surf. Proc. Land.* **22**: 623–639.

5. Edwards, T. K. and Glysson, G. D. 1999. *Field Methods for Measurement of Fluvial Sediment*. USGS Open-file Report Book, **3(2):** 1−97.
6. Folk, R. L. and Ward, W.C. 1957. Brazos River Bar: A Study in the Significance of Grain-Size Parameters. *J. Sedi. Petrol.,* **27(1)**: 3–26.
7. Hardy, M. and Cornu, S. 2006. Location of Natural Trace Elements in Silty Soils Using Particle-size Fractionation. *Geoderma,* **133**: 295–308.
8. Haritashya, U.K., Kumar, A. and Singh, P. 2010. Particle Size Characteristics of Suspended Sediment Transported in Melt Water from the Gangotri Glacier, Central Himalaya: An Indicator of Subglacial Sediment Evacuation. *Geomorphology*, **122:** 140–152.
9. Indorante, S. J., Hammer, R. D. and Koenig, P.G. 1990. Particle-size Analysis by a Modified Pipette Procedure. *Soil Sci. Soc. Am. J.,* **54**: 560-563.
10. Jillavenkatesa, A., Dapkunas, S. J. and Lum, L. H. 2001. *Particle Size Characterization.* US Department of Commerce, Technology Administration, National Institute of Standards and Technology; Washington, DC, 164 PP.
11. Khaledi Darvishan, A. V., Sadeghi, S. H. R., Vafakhah, M. and Gholami, L. 2008. Recognition of Effective Physical Characteristics of Watershed on Bed Sediment Morphometry (Case Study: Vaz River). *Iran-Water Resour. Res.,* **4(1):** 75-78.
12. Kim, J. Y. and Sansalone, J. J. 2008. Event-based Size Distributions of Particulate Matter Transported during Urban Rainfall-runoff Events. *Water Res.,* **42(10-11):** 2756-2768.
13. Kim, C. S. and Lim, H. 2009. Sediment Dispersal and Deposition Due to Sand Mining in the Coastal Waters of Korea. *Cont. Shelf Res.*, **29(1)**:194-204.
14. Krishnappan, B. G. 2000. *In situ* Size Distribution of Suspended Sediment Particles in the Fraser River. *J. Hydrol. Eng., ASCE*, 126: 561-569.
15. Liu, T. K., Odell, R. T., Etter, W. C. and Thornburn, T. H. 1966. A Comparison of Clay Contents Determined by Hydrometer and Pipette Method Using Reduced Major Axis Analysis. *Soil Sci. Soc. Am. J.,* **30**: 665-669.
16. Montagne, D., Cornu, S., Forestier, L. Le., Hardy, M., Josière, O., Caner, L. and Cousin, I. 2008. Impact of Drainage on Soil-forming Mechanisms in a French Albeluvisol: Input of Mineralogical Data in Mass-balance Modeling. *Geoderma,* **145:** 425-438.
17. Naik, P. K. and Jay, D. A. 2011. Distinguishing Human and Climate Influences on the Columbia River: Changes in Mean Flow and Sediment Transport. *J. Hydrol.*, **404(3-4)**: 259-277.
18. Naime, J. M., Vaz, C. M. P. and Macedo, A. 2001. Automated Soil Particle Size Analyzer Based on Gamma-ray Attenuation. *Comput. Electron. Agr.,* **31**: 295–304.
19. Neal, C., Robson, A. J., Wass, P., Wade, A. J., Ryland, G. P., Leach, D. V. and Leeks, G. J. L. 1998. Major, Minor, Trace Element and Suspended Sediment Variations in the River Derwent. *Sci. Total Environ.,* **210/211**: 163–172.
20. Peters, B. G. T. M. and Hulscher, S. J. M. H. 2006. Large-scale Offshore Sand Extraction: What Could Be the Results of Interaction between Model and Decision Process. *Ocean Coast. Manage.,* **49**: 164–187.
21. Poizot, E., Méar, Y. and Biscara, L. 2008. Sediment Trend Analysis through the Variation of Granulometric Parameters: A Review of Theories and Applications. *Earth-Sci. Rev.,* **86**: 15–41.
22. Putjaroon, W. and Pongboon, K. 1987. *Amount of Runoff and Soil Losses from Various Land-use Sampling Plots in Sakolnakorn Province, Thailand*. Forest Hydrology and Watershed Management-Hydrologie Forestiere et Amenagement des Bassins Hydrologiques (Proceedings of the Vancouver Symposium, August 1987; Actes du Co1loque de Vancouver, AoGt 1987).IAHS-AISH Pub 1, No. 167, 1987.
23. Rovira, A. and Batalla, R. J. 2006. Temporal Distribution of Suspended Sediment Transport in a Mediterranean Basin: The Lower Tordera (NE SPAIN). *Geomorphology,* **79**: 58–71.
24. Sadeghi, S. H. R., Kiani Harchegani, M. and Younesi, H. A. 2012. Suspended Sediment Concentration and Particle Size Distribution

and Their Relationship with Heavy Metals Contents, *J. Earth Sys. Sci*., **121(1)**:63-71

25. Sadeghi, S. H. R., Aghabeigi Amin, S., Vafakhah, M., Yasrebi, B. and Esmaeili Sari, A. 2006. Suitable Drying Time for Suspended Sediment Samples, Iran. *In Proceeding of International Sediment Initiative Conference*, Nov. 12-16, 2006, Khartoum, Sudan, 71 PP.
26. Sadeghi, S. H. R., Mizuyama, T., Miyata, S., Gomi, T., Kosugi, K., Fukushima, T., Mizugaki, S. and Onda, Y. 2008. Determinant Factors of Sediment Graphs and Rating Loops in a Reforested Watershed. *J. Hydrol.,* **356**: 271–282.
27. Sadeghi, S. H. and Saeidi, P. 2010. Reliability of Sediment Rating Curves for a Deciduous Forest Watershed in Iran. *Hydrol. Sci. J.,* **55(5):** 821–831.
28. Siakeu, J., Oguchi, T., Aokic, T., Esaki, Y. and Jarvie, H. P. 2004. Change in Riverine Suspended Sediment Concentration in Central Japan in Response to Late 20th Century Human Activities. *Catena,* **55**: 231–254.
29. Singh, K. P., Mohan, D., Singh, V. K. and Malik, A. 2005. Studies on Distribution and Fractionation of Heavy Metals in Gomti River Sediments: A Tributary of the Ganges, India. *J. Hydrol.,* **312**: 14–27.
30. Slattery, M. C. and Burt, T. P. 1997. Particle Size Characteristics of Suspended Sediment in Hillslope Runoff and Stream Flow. *Earth Surf. Proc. Land.,* **22**: 705-719.
31. Walling, D. E. 1988. Erosion and Sediment Yield Research: Some Resent Perspectives. *J. Hydrol.,* **100**: 113-141.
32. Walling, D. E. 1997. The Response of Sediment Yield to Environmental Change. In: "*Human Impact on Erosion and Sedimentation*", (Eds.): Walling, D. E. and Probst, J. L. IAHS Publ., IAHS Press, Wallingford, **245**: 77-89.
33. Walling, D. E. and Moorehead, P. W. 2004. The Particle Size Characteristics of Fluvial Suspended Sediment: An Overview. *Hydrobiologia,* **176/177**: 125-149.
34. Walling, D. E., Owens, Ph. N., Waterfall, B. D., Leeks, G. J. L. and Wass P. D. 2000. The Particle Size Characteristics of Fluvial Suspended Sediment in the Humber and Tweed Catchments, UK. *Sci. Total Environ.,* **251/252**: 205-222.
35. Walling, D. E. and Woodward, J. C. 1993. Use of a Field-based Water Elutriation System for Monitoring the *In situ* Particle Size Characteristics of Fluvial Suspended Sediment. *Water Res.,* **27**: 1413-1421.
36. Williams, N. D., Walling, D. E. and Leeks, G. J. L. 2007. High Temporal Resolution *In situ* Measurement of the Effective Particle Size Characteristics of Fuvial Suspended Sediment. *Water Res.,* **41:** 1081-1093.
37. Zapata, F. 2003. Handbook for the Assessment of Soil Erosion and Sedimentation Using Environmental Radionuclides, Kluwer Academic, 219 PP.
38. Zhang, Q., Xu, Ch., Becker, S. and Jiang, T. 2006. Sediment and Runoff Changes in the Yangtze River Basin during Past 50 Years. *J. Hydrol.,* **331**: 511-523.

نقش برداشت معدن شن و ماسه در توزیع اندازه ذرات رسوبات معلق در رودخانه جنگلی کجور، ایران

س. ح. ر. صادقی و م. کیانی‌هرچگانی

چکیده

در نتیجه فرسایش رسوبات از منبع اصلی خود جدا شده و به صورت ذرات معلق انتقال می‌یابند. مطالعه حاضر به بررسی تأثیر برداشت معدن شن و ماسه بر دانه‌بندی رسوبات معلق در حوزه آبخیز جنگل پژوهشی و

آموزشی دانشگاه تربیت مدرّس با مساحت حدوداً ۵۰۰۰۰ هکتار و در خروجی روخانه کجور می‌پردازد. ۵۱ نمونه آب طی آبان ۱۳۸۶ تا تیر ماه ۱۳۸۷ قبل، حین و بعد برداشت معدن شن و ماسه جمع آوری شدند. میزان ته‌نشینی ذرات اولیّه بر مبنای قانون استوکس می‌باشد که با روش پیپت اصلاح شده اندازه‌گیری شد. آنالیز نمونه‌ها نشان داد که برداشت معدن شن و ماسه تأثیر به‌سزایی در تغییر دانه‌بندی رسوبات معلق دارد. نتایج آزمون آماری t غیر جفتی نیز با سطح معنی داری کم‌تر از یک درصد برای درصد وزنی ماسه و لای و غلظت رسوبات معلق در دوره بعد و حین برداشت معدن شن و ماسه به‌ترتیب با مقدار ۷۴/۱۹±۱۳/۴ و ۱۳/۸±۹/۷۵، ۸۱/۷۷±۴/۵ و ۲/۹۶±۲/۷ درصد و ۷/۶۶±۷/۷ و ۰/۳۴±۰/۳ گرم در لیتر مؤید این مطلب می‌باشد. علاوه بر آن، اختلاف بین داده‌های هیدرولوژی و دانه‌بندی رسوبات معلق قبل و حین برداشت معدن در سطح یک درصد معنی‌دار نبوده که مشخصاً تاثیر متعاقب برداشت معدن بر تغییر دانه‌بند ی رسوبات معلق را تائید نمود.