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Variability of Bed Load Components in Different Hydrological Conditions

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A B S T R A C T

Study Region: The Educational and Research Forest Watershed of Tarbiat Modares University (Kojour), North of Iran.
Study focus: The present study was carried out in order to assess the temporal variation of amount and characteristics of bed load in different hydrological conditions. Towards this attempt, we measured the bed load and discharge using a standard flume at the watershed outlet in different temporal and hydrological conditions (from July 2011 to June 2012).
New hydrological insights: We found that the amount of the minimum, the mean and the maximum bed load were 3×10^{-8}, $6.15 \times 10^{-4} \pm 7.17 \times 10^{-4}$ and 4.38×10^{-3} kg s^{-1}, respectively. The minimum, the mean, and the maximum discharge were also 60, 334 ± 215.56 and 780 l s^{-1}, respectively. In low discharge conditions during summer, the fine grain sediments had the largest amount of bed load sediment. Coarse and medium-grained sediment transportation was higher in autumn and the early winter consistent with the occurrence of extreme rainfall and flood flows.

1. Introduction

Awareness of sediment loads behavior in river ecosystems is important for receiving waters, lakes and channel management (Lane et al., 2007; Raven et al., 2010; Kheirfam and Vafakhah, 2015). Bed load and suspended loads are the most common modes of sediment transport by rivers (Sadeghi and Kheirfam, 2015). The suspended load consists of fine particles influenced by the flow turbulence (Fredson and Deigaard 1994). While, the bed load consists of relatively large particles that move along the stream bed by rolling, sliding and/or hopping (Kabir et al., 2011).

Sediment load behavior is influenced by various factors such as climatic, hydrological, hydraulic and human intervention affecting sediment through changing discharge and watershed responses (Lana-Renault 2007, Sadeghi and Saeidi, 2010; Sadeghi and Kheirfam, 2015). Furthermore, the watershed responses and flow discharges in river may be changed directly due to human impacts on the river (Gonzalez-Hidalgo et al., 2013; Bisantino et al., 2015), land use change (Keesstra, 2007; Cerdà et al., 2009; Parras-Alcántara et al., 2016), pattern and type of crop (Rodrigo Comino et al., 2016a; Rodrigo Comino et al., 2016b), developmental activities and urbanization (Davudirad et al., 2016), and soil erosion control strategies on hillslopes (Keesstra et al., 2016; Cerdà et al., 2016; Kheirfam et al., 2017). Thus, sediment load does not necessarily follow a general

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and a constant pattern in different watersheds (Gonzalez-Hidalgo et al., 2013). So that, hydrological models are unable to accurately simulate the fluvial behavior of the watersheds (Kheirfam and Vafakhah, 2015).

Therefore, field measurements and analysis of variability and monitoring of sediment load are necessary in river management. Meanwhile, suspended load is measured by conventional sampling in many stations or it is estimated using empirical models leading to different levels of inaccuracy.

The measurement and spatial (Hicks et al., 1996), temporal (Rovira and Batalla 2006; Lana-Renault and Regüés, 2007), spatiotemporal (Hassan et al., 2008), morphometric, hydrologic and climatic (Restrepo et al., 2006) variations and the impact of human intervention (Sadeghi and Saeidi, 2010; Sadeghi and Kheirfam, 2015) on suspended load or its component variability have been well studied.

While, the field measurement and analyses of bed load variability have been rarely performed due to difficulties in field measurement and high time consumption and cost. Accordingly, the researchers tried to use the empirical (e.g., DuBoys, 1879; Meyer-Peter and Muller, 1948; Martin, 2003), numerical (e.g., Roushangar and Koosheh, 2015; Inoue et al., 2016) and computerical models (Langendoen et al., 2016) to estimate the bed load. In this regards, the physical characteristics of bed load particles are the main variables in the conceptualization and development process of the models (Chatanantavet and Parker, 2009). However, most of these models have been developed under limited laboratory conditions or with a few field data (Dang and Park, 2015). Additionally, the physical characteristics of bed load particles have a basic role on rate of bed load transportation in rivers which they vary in temporal and hydrological conditions (Kabir et al., 2011; Sadeghi and Kheirfam, 2015).

The results of pioneer studies have indicated that the bed load models particularly empirical equations could not properly show the bed load transportation and time variation in different conditions (Habibi and Sivakumar, 1994; Abrahart and White, 2001; Habersack and Laronne, 2002; Raven et al., 2010; Haddadchi et al., 2012; Sadeghi and Kheirfam, 2015). Whilst, the researchers have shown that the bed load rates at various times and hydrological conditions were highly variable (Lisle et al., 2000; Gomi et al., 2004; Sadeghi and Kheirfam, 2015; Sadeghi and Zakeri, 2015).

Although, many studies have been cited on application of differential equations and approaches for estimation of bed load but very limited studies have been conducted on temporal and hydrological variations of bed load generally employed indirect means. Yang and Huan (2001) investigated the applicability of 13 bed load equations using 3391 sets of laboratory and several rivers data. They concluded that no universal model could consistently estimate bed loads under different conditions. However, they believed that the studied model could be used for bed load estimation after calibration processes.

Martin (2003) have reported underestimation of the Meyer-Peter and Muller (1948) and Bagnold's (1980) equations in estimating bed load transport in Vedder River, Canada. Ryan and Dixon (2008) found that the runoff dominated by snowmelt had the maximum effect on suspended and dissolved loads, while the bed load transport depended on discharge variations. Popek (2010) studied the variability of bed load in flood events in the Zagożdżonka River, Poland. The results indicated that the bed load rate had a direct relationship with amount of discharge, water level, and slope. Haddadchi et al. (2012) used some common equations to estimate bed load transport. They observed that the bed load transportation was controlled by hydraulic characteristics and slope of the river and, bed sediments size. Haddadchi et al. (2013) also believed that the morphological characteristics of bed sediments in the rivers had an effective role in capability of empirical and numerical equations to estimate bed load. Sadeghi and Kheirfam (2015) found that behaviors of suspended load and bed load were controlled by climatic and hydrological factors, respectively. However, they reported that the effect of human manipulations in the river path on bed load transport was more than that on suspended load. Sadeghi and Zakeri (2015) also reported that the bed, suspended and wash load ratios were changed at temporal and hydrological conditions in the gravel bed river located in a forest watershed in Iran.

Several other researchers have also, used or developed the empirical relations and numerous bed load transport equations using field and laboratory data. They mainly emphasized that the amount of bed load varies with changes in discharge (Torizzo and Pitlick, 2004; Lana-Renault and Regüés, 2007; Raven et al., 2010) and human activity (Kondolf et al., 2002; Sadeghi et al., 2008; Ashraf et al., 2011). Hardy et al. (2010), Monsalve et al. (2016) and Wyss et al. (2016) also believed in great variations in amount and even grain sizes of bed load directly controlled by temporal variation of flow discharge.

Scrutinizing existing literatures clearly showed that there were limited studies on temporal variations of bed load despite of their emphases on inapplicability of empirical equation and approaches to simulate conditions different from area where the equations have been originally developed. In addition, physical characteristics of bed load particles have a severe effect on the precision of the estimates on bed load models (Sadeghi and Zakeri, 2015; Monsalve et al., 2016; Wyss et al., 2016). Nonetheless, physical characteristics of bed load particles vary in different temporal and hydrological conditions. It therefore clearly justifies the necessity of conducting researches on studying bed load behaviors and components under different conditions. Thus, we assessed the temporal variation of bed load amount and grain size during a short study period of some one year with different hydrological behavior. The study was conducted in the Kojour River draining to the Caspian Sea in north of Iran.