# Drivers of Sedimentary Fluxes Assessment in Alpine Catchments

V. O. Bazilova(✉), S. R. Chalov, and A. S. Tsyplenkov

Faculty of Geography, Department of Hydrology, Lomonosov Moscow State University, Moscow, Russia
varyabazilova@gmail.com

**Keywords:** Glacierized catchment · Caucasus mountains · Sediment yield · Erosion modeling

## 1 Introduction

The sediment yield formation in the mountain catchments is a complex process, which is affected by many parameters, such as watershed processes (landslides, glacier ablation), in-channel processes regime, synoptic situation, etc. (Warburton 1990). The case study Djankuat river (Central Caucasus) is located below Djankuat glacier which regime during melting season causes significant sediment fluxes fluctuations (both daily and seasonal), Djankuat glacier is the main water source (Vasilchuk et al. 2016). Due to global changes in the environment, glacier melting in the headwaters plays the key role in the erosion and accumulation patterns (Gurnell et al. 1996).

Integrated glaciological and hydro-meteorological monitoring of this area (and Djankuat glacier as a mass-balance glacier in particular) is done by Lomonosov Moscow State University (Golubev et al. 1978) within WGMS research activities since 1965, however, sediment yield has never been evaluated before.

The present research is a field-based study, which aims to get an understanding of the impact of modern changes in rivers regime on sedimentation rates and relative contributions of different sediment sources input to the river sediment discharges. The research is focused on complex investigations of watershed processes in the glacial catchment (hydrological, geomorphological). Processes in Djankuat catchment, such as sediment transport in and to river channels are strongly influenced by climatic conditions, particularly when heavy precipitation and warmer climate triggers high-concentrated flows in association with snow/glacier melting in the catchment area.

## 2 Methods

The aim of the study requires the use of field monitoring records and model estimations. Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt 1977) was used. The database, containing hydrological, meteorological, glaciological and sediment data, obtained during 2015 and 2016 field seasons at the Djankuat catchment


S. Chalov et al. (Eds.): *Climate Change Impacts on Hydrological Processes and Sediment Dynamics: Measurement, Modelling and Management*, SPEES, pp. 34–38, 2019.
https://doi.org/10.1007/978-3-030-03646-1_6

was created. It contains 3 h resolution information, which has been received, using linear interpolation between observed parameters. The empirical data is used to calculate the total sediment yield and water runoff, and to distinguish "high-water periods" (floods) and for the estimate the parameters, affecting the sediment yield formation processes. Besides that, the estimation of the amount of eroded soil, which are brought to the river during floods of different genesis was also based on the in-situ monitoring data.

MUSLE model is based on the following formula:

$$Y = 11.8 \times (h \times Q_{\max})^{0.56} \times K \times L \times S \times C$$

where:

| | |
|---|---|
| $Y$ | is a potential erosion (t × $ha^{-1}$ per year), |
| $h$ | water runoff of the event ($m^3$), |
| $Q_{max}$ | maximum observed discharge during the flood event ($m^3 \times s^{-1}$), |
| $K$ | soil erodibility (based on soil grain size composition), |
| $C$ | vegetation factor (based on the vegetation type), |
| $LS$ | topography factor (based on a length and slope of the surface). |

MUSLE model used to distinguish most valuable sediment sources at the catchment. The watershed was divided into three parts, depending on the surface type: glacier-covered, in-channel and glacier-free terrain. According to that, the following sediment budget-equation was used:

$$W = W_1 + W_2 + W_3$$

| | |
|---|---|
| $W$ | total sediment yield, |
| $W_1$ | sediment yield from a glacier covered surface, |
| $W_2$ | sediment yield from a glacier-free surface, |
| $W_3$ | in-channel erosion. |

As mentioned above, total sediment yield – is based on monitoring data, sediment yield from a glacier-free surface was estimated with the MUSLE model, sediment yield from a glacier covered surface is estimated as a difference between these parameters. In-channel erosion evaluation was based on the sediment transport capacity, according to Rossinskiy-Kuzmin model (Rossinskiy and Kuzmin 1964), and its comparison with an observed sediment discharge. Average measured parameters are stated in Table 1; (Fig. 1).

**Table 1.** Average parameters, measured during field campaigns in 2015 and 2016.

| | Water discharge ($m \times s^{-1}$) | Precipitation (mm) | SSC ($g \times m^{-3}$) | Sediment discharge ($g \times s^{-1}$) | Total sediment yield (t) | Suspended sediment yield (t) | Bed-load sediment yield (t) |
|---|---|---|---|---|---|---|---|
| 2015 | 2.1 | 507 | 663.7 | 2333.4 | 20,967 | 18241 | 2726 |
| 2016 | 1.6 | 474 | 499 | 798 | 8578 | 7426 | 1152 |

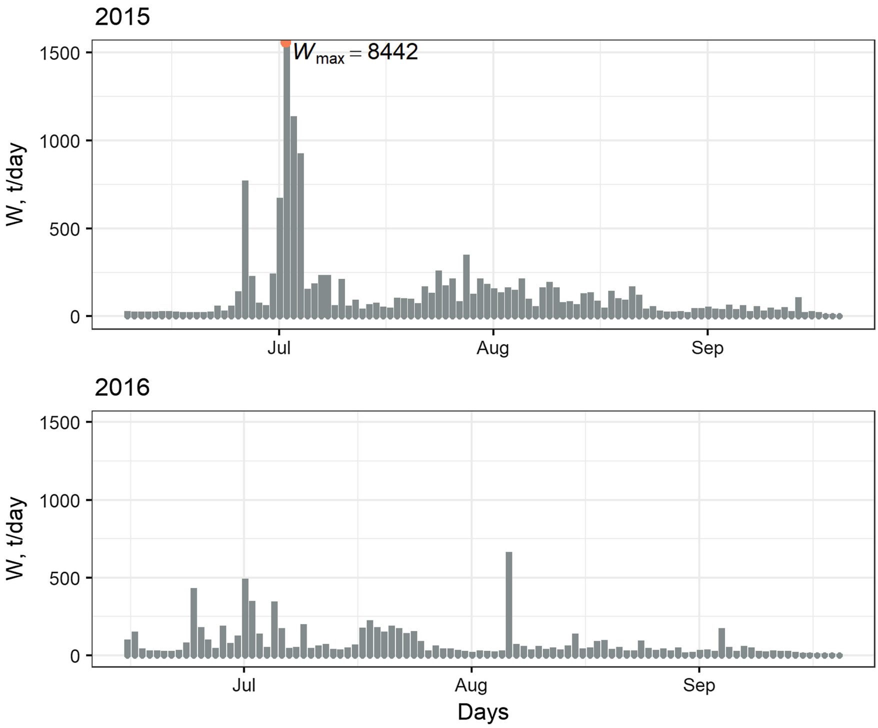


**Fig. 1.** Suspended Sediment Load during 2015–2016 ablation periods.

## 3 Conclusions

During 2015 and 2016 field seasons 21 floods were observed. For each of them, the following parameters were calculated: sediment yield, percent of total sediment yield, maximum discharge and the sum of precipitation. The genesis of the flood was distinguished and the chronological relationship between suspended sediment concentration values (*SSC*) and water discharge (*Q*) was built. According to the in-situ data, the correlation matrixes between measured parameters were used to distinguished valuable ones. The parameter is considered valuable for predicting the sediment yield if the Pierson correlation *r* is higher, then 0.7.

The linear regression was used to build SSC regression models from observed hydrometeorological parameters for each flood, where valuable parameters were found. The increase of the water level and discharge affects the bed and bank erosion, so it can be considered as the main parameter, however, it is not the only one. The other parameters, affecting SSC and sediment yield were air temperature and precipitation.

However, these equations don't reproduce the SSC during floods very well, and can't be used as universal models, due to the different flood origin. Some of the floods are caused by an intensive glacier melt, due to the amount of income solar radiation and temperature, some – by the heavy precipitation events. The origin of the flood determines the main sediment sources. However, according to the modeling results, the erosion of the lateral moraine and the debris cover on the Djankuat glacier is almost the exceptional source of the sediment yield during all high-water periods, even during high precipitation caused floods (Fig. 2).

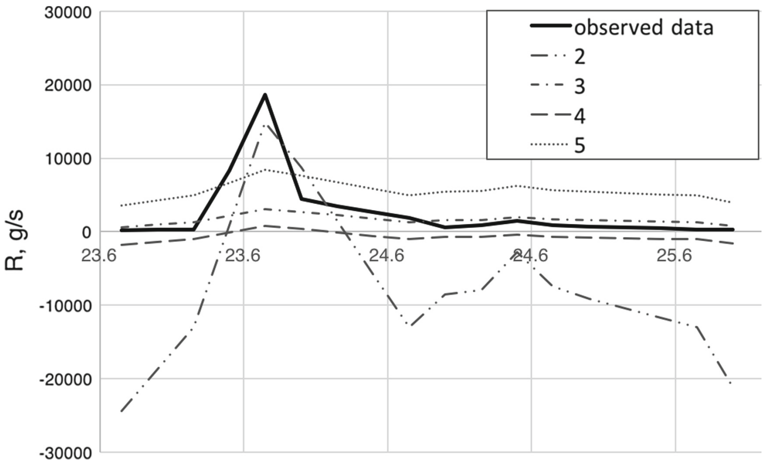


**Fig. 2.** Examples of Linear Regression Models.

The contribution of all considered floods to the total sediment yield varies from 0.4 to 18% with the exceptions in the forms of big landslides on the watershed (they form up to 40% of the total sediment yield).

MUSLE model was applied for all floods to determine the main sources of the sediment load and to estimate the contribution of the reel erosion. The rill and inter-rill erosion from the glacier-free part of the Djankuat river watershed only forms <1% of the sediment load.

Bed-load transport corresponds to the sediment grain size composition and the river discharge. Since the sediment transport capacity of the Djankuat river is more than 1000 times lower, that the observed values of the sediment discharges, we can assume, that the accumulation prevails in semi-flat sections of the channel. The average bedload sediments rate is 13% of the total sediment yield. However, up to 25% of the bed-load sediments in 2015 were observed during the extreme mud-flow event, caused by a combination of linear and gully erosion and heavy precipitation.

## References

Golubev LN, Durgerov MB, Markin VA, Berry LB, Sukhanov LA, Zolotarev EA, … Artuyunov YG *Djankuat glacier (Central Caucasus)*. Hydrometeoizdat, Leningrad (1978) (In Russian)

Gurnell, A., Hannah, D., & Lawler, D.: Suspended sediment yield from glacier basins. In: IAHS Publications-Series of Proceedings and Reports-Intern Assoc Hydrological Sciences, vol. 236, pp. 97–104 (1996)

Williams, J.R., Berndt, H.D.: Sediment yield prediction based on watershed hydrology. Trans. of the ASAE **20**(6), 1100–1104 (1977). https://doi.org/10.13031/2013.35710

Rossinskiy, K.I., Kuzmin, I.A.: Balance method for the calculations of bed of the stream deformations. Works Hydroproekt, Sb. **12**, 265–271 (1964). (In Russian)

Vasilchuk, Y.K., Rets, E.P., Chizhova, J.N., Tokarev, I.V., Frolova, N.L., Budantseva, N.A.: Hydrograph separation of the Dzhankuat River, north caucasus, with the use of isotope methods. Water Res. Regime Water Bodies, **43**(6), 847–861 (2016). https://doi.org/10.1134/S0097807816060087

Warburton, J.: An alpine proglacial fluvial sediment budget. Geografiska Annaler Series A Phys. Geogr. **72**(3–4), 261–272 (1990). https://doi.org/10.1080/04353676.1990.11880322