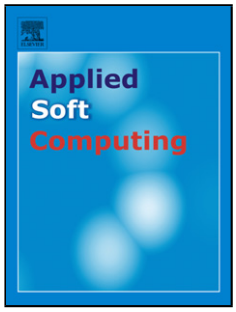

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Fuzzy threshold for the initiation of sediment motion

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Highlights (for review)

- The threshold for the initiation of sediment motion in rivers is considered to be a fuzzy set to express partial sediment entrainment. The dimensionless critical shear stress is calculated as a fuzzy set by incorporating the fuzziness of the individual angle of grain contact and the turbulence intensity.
- The proposed methodology is a combination of both the (precise) moments balance and forces balance equations (physically-based equations) and the extension principle of fuzzy sets and logic.
- A measure to compare the produced fuzzy dimensionless critical shear stress and the exerted dimensionless shear stress (crisp number) is proposed, which is based on the concept of fuzzy subtraction and the fuzzy reliability measure.
- The proposed methodology does not require a training process since it is based on a white-box model. However, the comparison with experimental data indicates a sufficient approach.

Abstract

The present paper considers the threshold for the initiation of sediment motion to be a fuzzy set by taking into account the uncertainty related to individual sediment positioning and turbulence intensity. Incipience of sediment motion across a stream-bed occurs gradually, and a fuzzy set facilitates the notation of partial sediment transport in the computations. For the derivation of this fuzzy threshold, the formula developed in Zanke, U.C.E. (2003), "On the influence of turbulence on the initiation of sediment motion", Int. J. Sediment Res., 18(1), 17-31, for the computation of dimensionless critical shear stress is extended accordingly by using, instead of crisp values in order to describe the angle of grain contact and the turbulence intensity, fuzzy numbers. This can be achieved by exploiting the extension principle of fuzzy sets and logic. Hence, the proposed formula generates two three-dimensional surfaces by means of the extension principle of fuzzy sets, which define the lower and upper limits of the dimensionless critical shear stress membership function with respect to the shear Reynolds number and the relative roughness. The benefit of this approach, when compared to an approach that solely utilizes characteristic or average values, is that it can predict partial sediment transport of the most susceptible to movement particles, which is very common in gravel-bed streams even for bankfull flow conditions. In addition, a measure to compare the produced fuzzy dimensionless critical shear stress with the exerted dimensionless shear stress, is proposed, which is based on the concept of fuzzy subtraction and takes into account the whole shape of