

A GENERAL SEDIMENT TRANSPORT MODEL FOR LINEAR INCISIONS

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1. Introduction

Previous research has shown that the functional relationship between sediment transport and shear stress, discharge and slope is non-linear. The different datasets that support this hypothesis are however all derived from flume experiments or river channels. No calibration was done at the field scale. Recently, Istanbuluoglu et al. (2003) successfully calibrated the sediment transport function with field data from eroding gullies in the Idaho Batholith. However, the field data presented covered only a relatively limited range of condition. In this study, more field data is presented that supports the field-scale calibration over a wider array of shear stress conditions in the lower range.

2. Materials and methods

2.1. Theoretical background

Sediment transport is often described by a power relation of shear stress or of discharge and slope. Many existing bedload and total load equations can be written in a similar functional form:

$$q_s^* = \beta \tau_c^p \quad (1)$$

where q_s^* is the dimensionless sediment discharge,

$$q_s^* = \frac{q_s}{\sqrt{g s' d^3}} \quad (2)$$

With q_s is the sediment discharge rate, g is the acceleration of gravity, s' and d are, respectively, the submerged specific gravity and the diameter of the sediment particles. τ_c is the dimensionless shear stress.

$$\tau_c = \frac{\tau}{\gamma s' d} \quad (3)$$

τ is the shear stress and γ the unit specific weight of the soil particles. β and p are coefficients, the first defined by the equation:

$$\beta = \kappa (1 - \tau_{c0} / \tau_c)^p \quad \tau_c > \tau_{c0} \quad (4)$$

τ_{c0} is the dimensionless critical shear stress and κ is another coefficient. Although this expression was originally proposed for the description of the bed load, it was successfully applied for total load sediment transport capacity by Istanbuluoglu et al. (2003) for the description of eroding gullies. These authors estimated the q_s^* and τ_c pairs from field data.

$$q_s^* \propto \frac{V_g}{A^{m_w} S^{n_w}} \quad (5)$$

$$\tau_c \propto A^{m_r} S^{n_r} \quad (6)$$

Where V_g is the volume of lost soil, A is the runoff contributing area, S is the local slope and m_w , n_w , m_r and n_r are coefficients.

2.2. Study area

The goodness of fit of the sediment transport relationship described above was computed using field data from an olive orchard near Baena in Andalusia, Spain, (Fig. 1). In a hillslope of 6600 m² under olive plantation, draining towards a large, permanent gully, detailed map was prepared of linear incisions. Total station was used to measure local topography and eroded volumes were measured with tape measures.



Fig. 1. Location of the study area within Spain.

3. Results and discussion

The pattern of the linear incision is shown in Fig. 2.

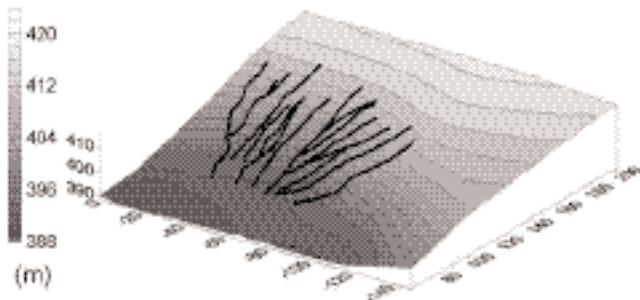


Fig. 2. Spatial distribution of the linear erosion features.

Once the proper values of the coefficients were computed, the dimensionless shear stress and sediment discharge data were inserted into the same figure of Istanbulluoglu et al. (2003), shown in Fig. 3. Note that the abscissa of this figure is not the dimensionless shear stress but a transformed version τ'_s .

$$\tau'_s = \tau_s (1 - \tau_{sc} / \tau_s) \quad (7)$$

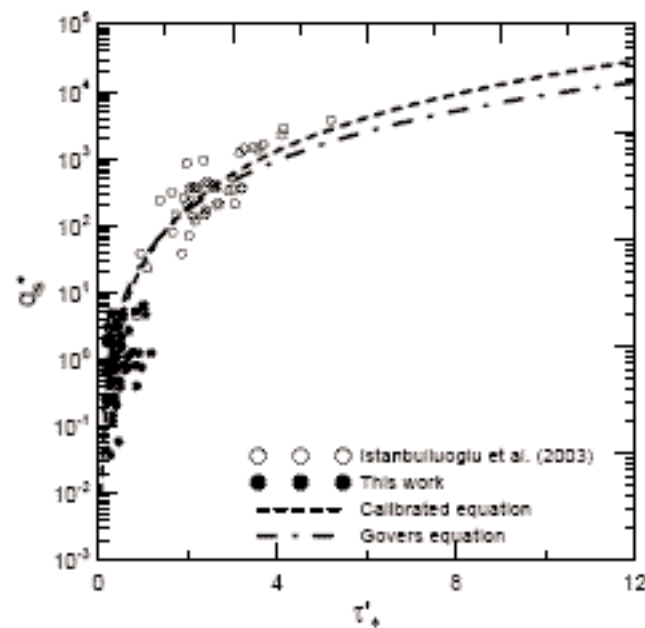


Fig. 3. Relationship between the dimensionless sediment discharge and transformed shear stress for linear incisions under Baena field conditions.

The calibrated equation of Fig. 3 corresponds to a linear regression curve fitted to the original Istanbulluoglu et al. (2003) data, whose equation was

$$q_s^* = 26.6 (\tau'_s)^{2.91} \quad (8)$$

The data from Baena fit well in this equation. Fig. 3 also includes the Govers (1992) empirical relationship

$$q_s^* = \kappa_G (\tau'_s)^{2.457} \quad (9)$$

As remarked by Istanbulluoglu et al. (2003), this equation is fairly close to the calibrated equation.

4. Conclusions

The acquired results, plotted in Fig. 3, agree well with the relationship for the lower range of values of (8). The agreement of the data is remarkable given the different conditions and the small dimension of the linear incisions. These data correspond to the boundary between rills and gullies and show the universal applicability of this sediment transport equation. Although a more detailed study is required to confirm these observations, the presented conclusions are relevant for the development of erosion models.

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