Supplementary Materials

Supplement S1 – Selection of Parameters

The inclusion of every available user-defined parameter in a Global SA would produce an unwieldy set of results and result in a prohibitively large amount of simulations. To narrow the parameters to a manageable set it was necessary to exclude some values. Those included were selected either due to their known importance to the model (due to user knowledge and or evidence based on past analysis), or likely uncertainties due to being reliant on field observations or similar. Likewise, those excluded were known to be negligible from user experience, reasonable global values can be set against easily obtainable values, or past studies have examined their influence on model behaviour in similar model set ups. Table S1.1 lists all the user-defined parameters and the justification for inclusion or otherwise.

Table S1.1 – List of User-Defined Parameters (excluding those associated with the Dune and Soil Development functions) in CAESAR-Lisflood v1.9b, and the justification for their inclusion or exclusion from the Global SA.

Parameter	Used?	Justification
Minimum Time Step	n	Tested previously and shown to be negligible (Ziliani et al., 2013)
Maximum Time Step	n	Not likely to have an influence, is used to make sure the model does not miss storms in the timeseries
Memory Limit	n	Not required for these model set ups
Grain Size Set	y	Based on field observations – can be highly variable spatially, yet is applied as a global distribution. Is a source of uncertainty in the model
Suspended Sediment	n	Tested previously and shown to be negligible (Ziliani et al., 2013)
Fall Velocity	n	Only used when Suspended Sediment is active
Bedrock Erosion Threshold	n	There is no representation of bedrock in the model set ups
Bedrock Erosion Rate	n	There is no representation of bedrock in the model set ups
Sediment Transport Model	y	These Laws are based on major simplifications of physical processes and are a source of uncertainty
Maximum Velocity Used to Calculate Tau	n	Is used to limit super critical flows and not required for these model set ups

Maximum Erosion Rate	y	Tested previously and shown to have a high influence on the model outputs (Ziliani et al., 2013)
Active Layer Thickness (m)	n	Is required to be at least 4x Maximum Erosion Rate so was not varied
Sediment Recirculation	n	Not used in catchment mode
In Channel Lateral Erosion Rate	y	Likely to have an influence on the model outputs
Lateral Erosion Rate		Tested previously and shown to have a low influence on model outputs (Ziliani et al., 2013), but the formulation is different in CAESAR-Lisflood to the CAESAR previous tested so should be repeated in case
Number of Passes for Edge Smoothing Filter	n	Related to the Lateral Erosion Rate Tested previously and shown to have a high influence on model outputs in a braided channel reach (Ziliani et al., 2013), less likely to be influential in catchment model
Number of Cells to Shift Lateral Erosion Downstream	n	Related to Lateral Erosion Rate
Maximum Difference Allowed in Cross Channel Smoothing	n	Related to Lateral Erosion Rate
‘m’ Value	n	The model’s response to this value was extensively tested in Coulthard and Van De Wiel (2017) in the Upper Swale
Vegetation Critical Shear Stress	y	Tested previously and shown to have a medium influence on the model (Ziliani et al., 2013)
Grass Maturity Rate (yrs)	y	Likely to have non-linear interaction with Vegetation Critical Shear Stress, and based on catchment conditions
Proportion of Erosion That Can Occur When Vegetation in Fully Grown	n	Likely to interact with other vegetation parameters and erosion rates. Commonly kept at the default rate of 0.1, as here
Creep Rate	y	Influence is likely to be different over different catchments and timeframes
Slope Failure Threshold		This value is normally fixed as a global value – any uncertainty may have an influence on the model
Soil Erosion Rate	n	Not likely to have an influence in these model set ups
Input/Output Difference Allowed	y	This value is set to determine when the model runs in steady state and is often set using mean discharge values if available. It makes the model more efficient by skipping over periods which are likely to be geomorphically insignificant. It is important to test how this assumption influences model outputs

Minimum Q for Depth Calculation	y	Tested previously and shown to be negligible (Ziliani et al., 2013), but is more likely to have an impact in catchment mode
Maximum Q for Depth Calculation	y	This parameter is likely to have an impact in catchment mode
Water Depth Threshold Above Which Erosion Will Happen (m)	n	Tested previously and shown to have a low influence on model outputs (Ziliani et al., 2013)
Slope for Edge Cells	y	This value is usually measured either in the field or based on the DEM. Uncertainty and observation error may influence model outputs, and in reality the value may be temporally non-stationary
Evaporation Rate (m/day)	y	May have an influence and will be non-stationary due to seasonality and climatic changes
Courant Number	n	Is used to reduce instability in the model
hflow Threshold	n	Likely to be of negligible consequence
Froude # Flow Limit	n	Likely to have an impact on the model outputs, but can also cause instabilities in the model
Manning's n Coefficient	y	Parameter commonly used to calibrate the Lisflood-FP model. Is represented as a global value, but can be non-stationary temporally and spatially. Can be constrained by field measurements but subject to observation uncertainty

Supplement S2 – Analysis on Upper Swale based on Sediment Transport Law

The choice of Sediment Transport Law has been shown to be the most influential parameter for the Upper Swale. In this Appendix the EEs for each parameter are divided into two groups – those which used Wilcock & Crowe and those which used Einstein. The results show that the model behaves in a similar fashion regardless of the Sediment Transport Law is selected. The non-linear interactions of parameters such as Manning's n Coefficient and Grain Size Set are reduced when the choice of Sediment Transport Law is accounted for.

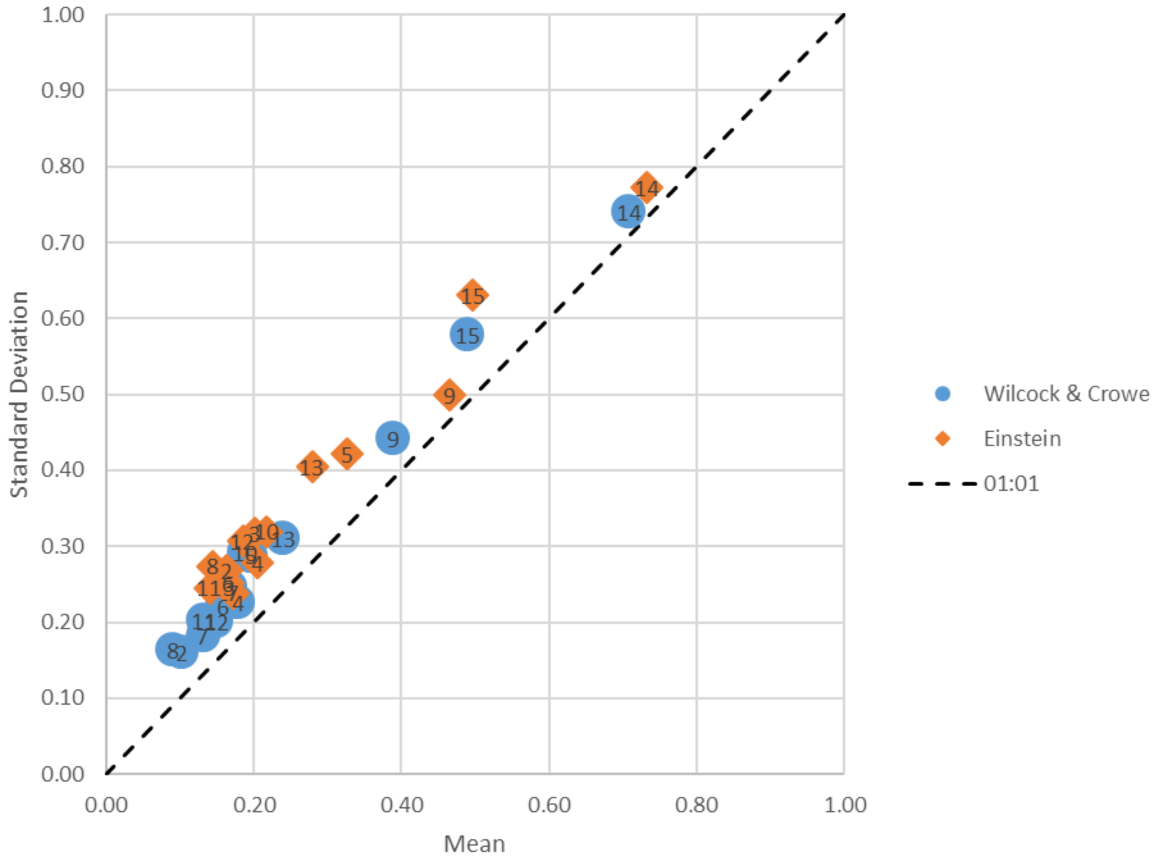

Figure S2.1 – Aggregated scores using each Sediment Transport Law for all Elementary Effects where: 2 = Maximum Erode Limit; 3 = In-Channel Lateral Erosion Rate; 4 = Lateral Erosion Rate; 5 = Vegetation Critical Shear Stress; 6 = Grass Maturity Rate; 7 = Soil Creep rate; 8 = Slope Failure Threshold; 9 = In/Out Difference; 10 = Minimum Q Value; 11 = Maximum Q Value; 12 = Slope for Edge Cells; 13 = Evaporation Rate; 14 = Manning's n Roughness Coefficient; and 15 = Grain Size Set.

Table S2.1 – Parameters ranked by means for each Sediment Transport Law from the aggregated scores for all Elementary Effects where: 2 = Maximum Erode Limit; 3 = In-Channel Lateral Erosion Rate; 4 = Lateral Erosion Rate; 5 = Vegetation Critical Shear Stress; 6 = Grass Maturity Rate; 7 = Soil Creep rate; 8 = Slope Failure Threshold; 9 = In/Out Difference; 10 = Minimum Q Value; 11 = Maximum Q Value; 12 = Slope for Edge Cells; 13 = Evaporation Rate; 14 = Manning's n Roughness Coefficient; and 15 = Grain Size Set.

Rank (by mean)	Wilcock & Crowe	Einstein
1	14	14
2	15	15
3	9	9
4	13	5
5	5	13
6	10	10
7	4	4
8	3	3
9	6	12
10	12	7
11	11	6
12	7	2
13	2	8
14	8	11

References

Coulthard, T. J. and Van De Wiel, M. J.: Modelling long term basin scale sediment connectivity, driven by spatial land use changes, Geomorphology, 277, 265–281, doi:10.1016/j.geomorph.2016.05.027, 2017.

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