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How long is a hillslope?

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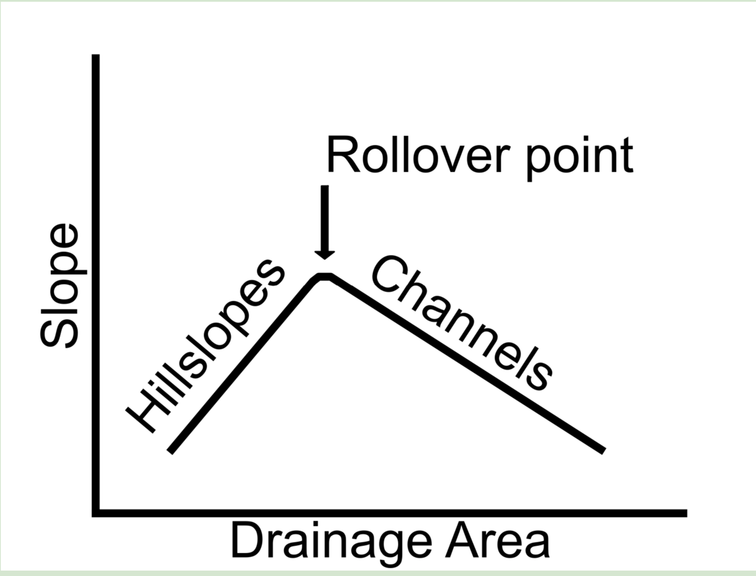
Hillslope length is a fundamental parameter of landscapes which governs sediment and water transport. It controls soil erosion and landslide hazard.
Yet we have no robust method to quantify it.

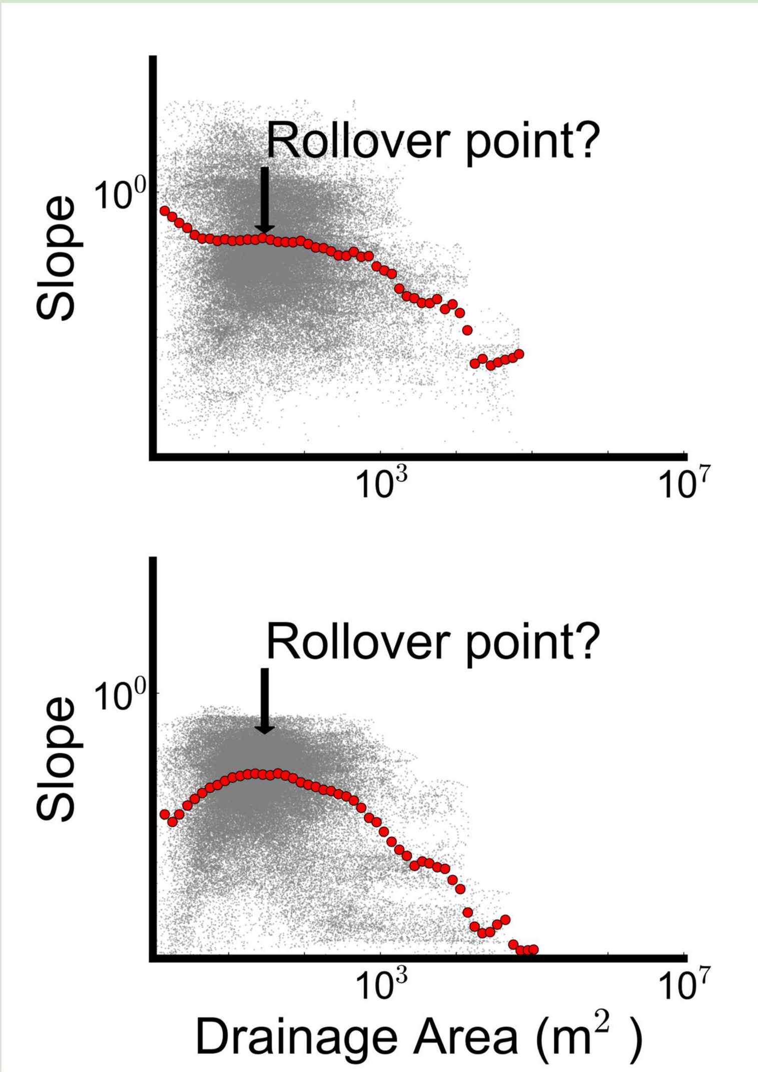
1. Do slope-area plots work?

THEORY:
Plots of local slope against upslope drainage area in a catchment are predicted to follow a 'boomerang' shape. The rollover point corresponds to the threshold drainage area at which hillslopes transition into channels. This area can be converted into a length by dividing it by the unit contour width (Roering *et al*., 2007).



PRACTICE:
The raw data (grey points) are very noisy and must be smoothed and binned in order to identify a trend (red circles). Attempting to use this technique across a landscape presents a number of problems:

- Extensive user supervision is required.
  - Parameters must be manually adjusted for each basin.
- Basins must be large enough to generate enough data points.
- Converting drainage area into length requires simple upslope geometry.
- The results are basin average values and cannot be used to study variations within a basin.

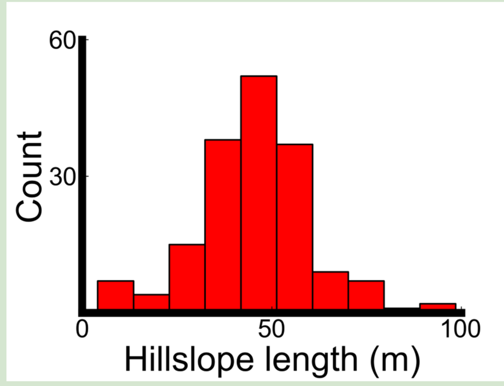


Slope-area plots give inconsistent hillslope length results at a landscape scale. They are sensitive to free parameters and the results are difficult to reproduce.

2. Inverting drainage density

The inverse of drainage density provides a measure of catchment average hillslope length (Tucker *et al*., 2001). This value can be rapidly calculated for any catchment, assuming an accurate constraint on the location of the channel network.

Little variation is observed across a landscape. This indicates that large changes in valley scale are not captured when using this technique.

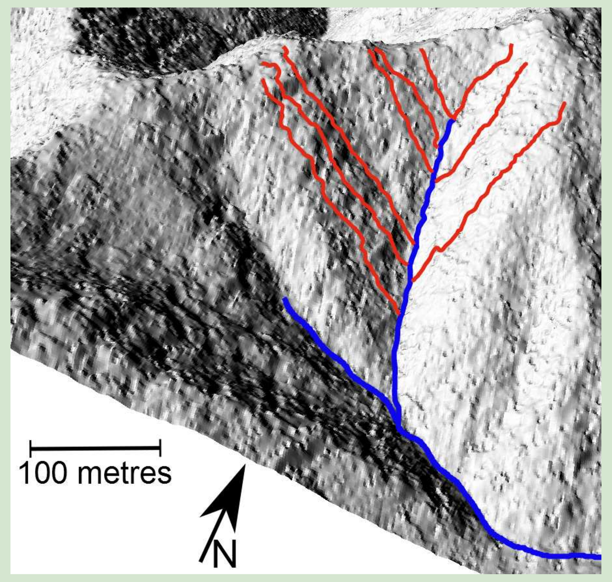


3. Measuring hillslopes directly

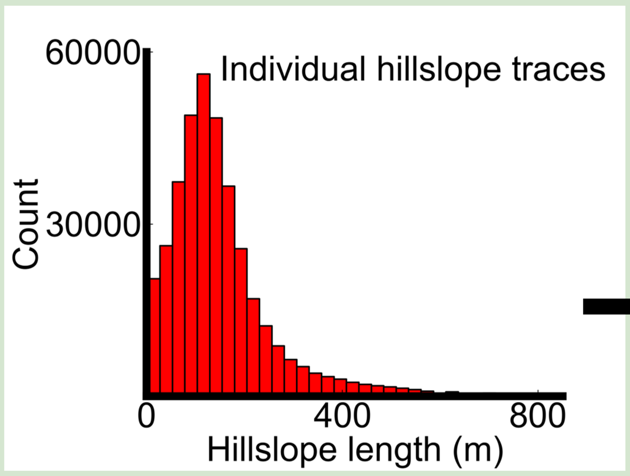
Slope-area plots perform poorly, and drainage density does not capture the true variation of hillslope lengths in a landscape.

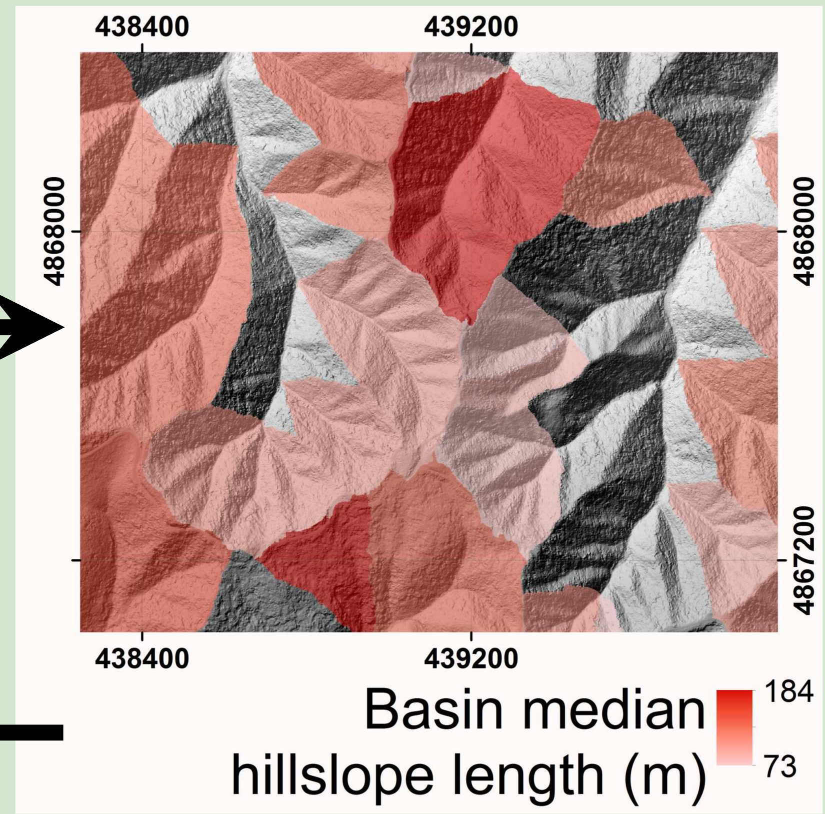
To robustly measure hillslope length at a range of spatial scales direct traces of overland flow length from hilltop to channel are employed.

Flow is routed across the DEM as a point source travelling across each cell in the direction defined by triangular facets fitted to each cell (Tarboton, 1997).



This produces an unprecedented scale of hillslope length measurements with over 150,000 traces measured in a 50 km^2 area. These data can be interpreted at a range of spatial scales:

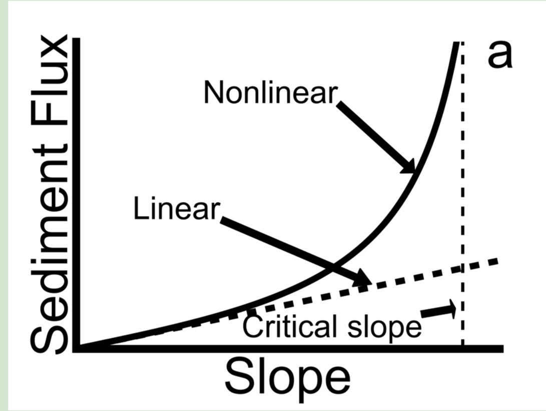


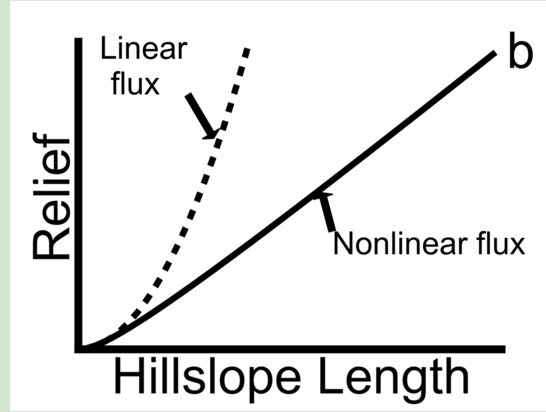


Landscape average hillslope length = 129 m

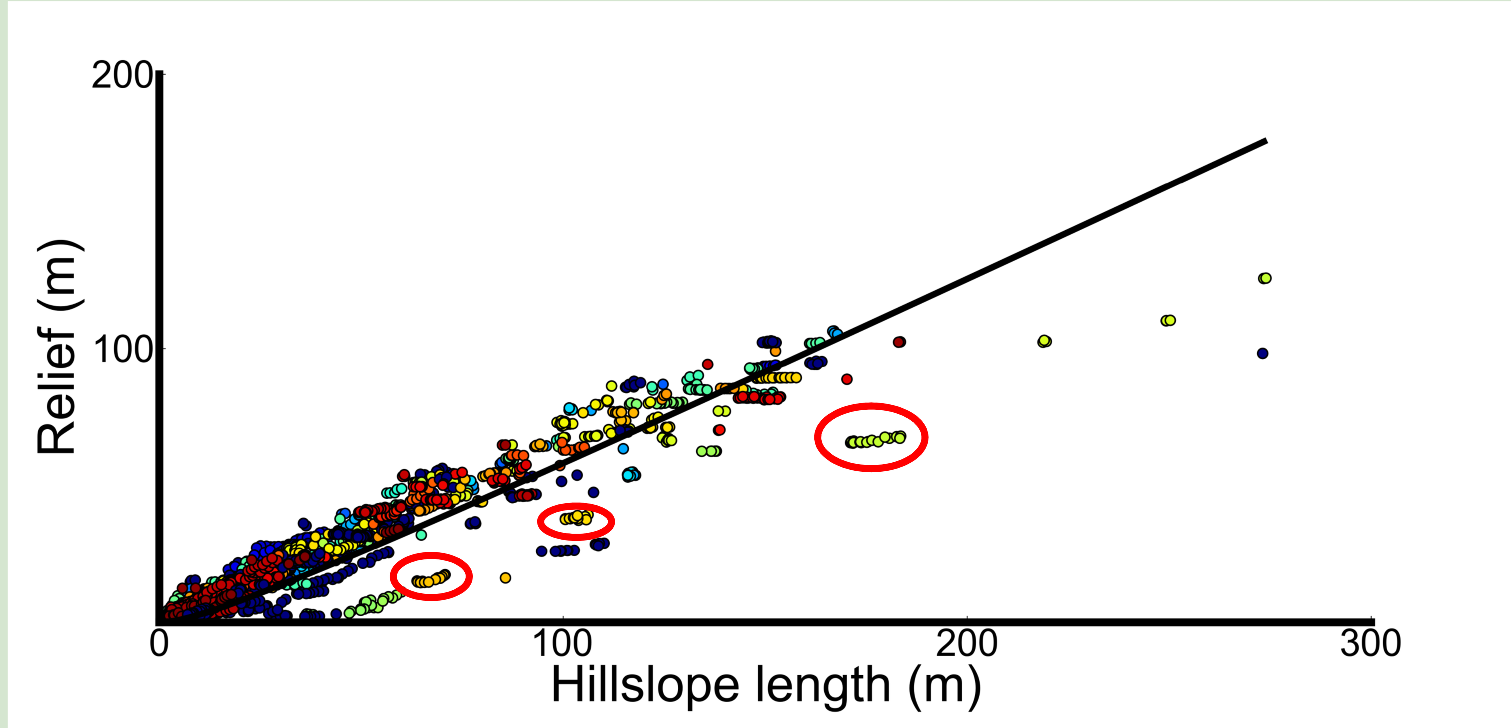
4. Evidence for nonlinear flux

This density of hillslope length measurements allows the nonlinear sediment transport law (Roering *et al*., 1999) (a) to be tested by considering the predicted relief hillslope length relationship (b).





Using published parameters for the Oregon Coast Range (Roering *et al*., 2007) we predict a critical slope of 0.7, lower than the previously reported value (1.2).



Data points are coloured by second order drainage basin, indicating the spatial heterogeneity in measurements. The circled points which fall below the main data cluster may be indicative of basins eroding at a slower rate than the landscape as a whole.

5. Conclusions

Direct measurements are more robust, providing a better constraint on hillslope length than previous methods.

We can now estimate hillslope length at a range of spatial scales.

Relationships between hillslope length and relief support the nonlinear model of hillslope sediment transport.

Hillslope length relief relationships may identify variations in erosion rates across landscapes.

Acknowledgements

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Code Availability

The software used to for this analysis is open source. Visit **bit.ly/163ehmQ**, scan the QR code or email me (s.grieve@ad.ac.uk) for a copy of the code.

References

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G. E. Tucker, F. Catani, A. Rinaldo, R. L. Bras, *Geomorphology* ***36, 187 (2001).***
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