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H02 – Using Fingerprinting and Modelling Techniques to Explore Transfer and Connectivity in Catchment Sediment Systems

CONNECTIVITY IN AGRICULTURAL LANDSCAPES; DO WE NEED MORE THAN A DEM?

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Rationale

Digital Elevation Models (DEMs) are an input to all watershed-scale erosion models. Often, the DEM is pre-smoothed to avoid blind pits. Topography obviously influences flow pathways, and topography-driven flow routing is readily implemented by models in a GIS

BUT

Topography-driven routing, by itself, can work adequately in natural, or minimally managed, landscapes. But in agricultural landscapes this approach neglects most anthropogenic interventions. These interventions may have a major role in increasing and / or decreasing the connectivity of flow (water and sediment)

Rationale

In agricultural landscapes, the connectivity of flow (water and sediment) is strongly influenced by anthropogenic influences which operate at a range of scales. These influences significantly affect both rates of erosion on hillslopes, and the emergent patterns of flow which deliver runoff and sediment from hillslopes to permanent channels

Calibration allows catchment-scale erosion models, in which flow routing is influenced solely by topography, to perform adequately (i.e. match observed and predicted runoff and erosion rates) at the catchment outlet. But such models do a poor job of replicating these emergent patterns of flow, and hence a poor job of locating the within-catchment hillslope hotspots which are the source of this runoff and erosion

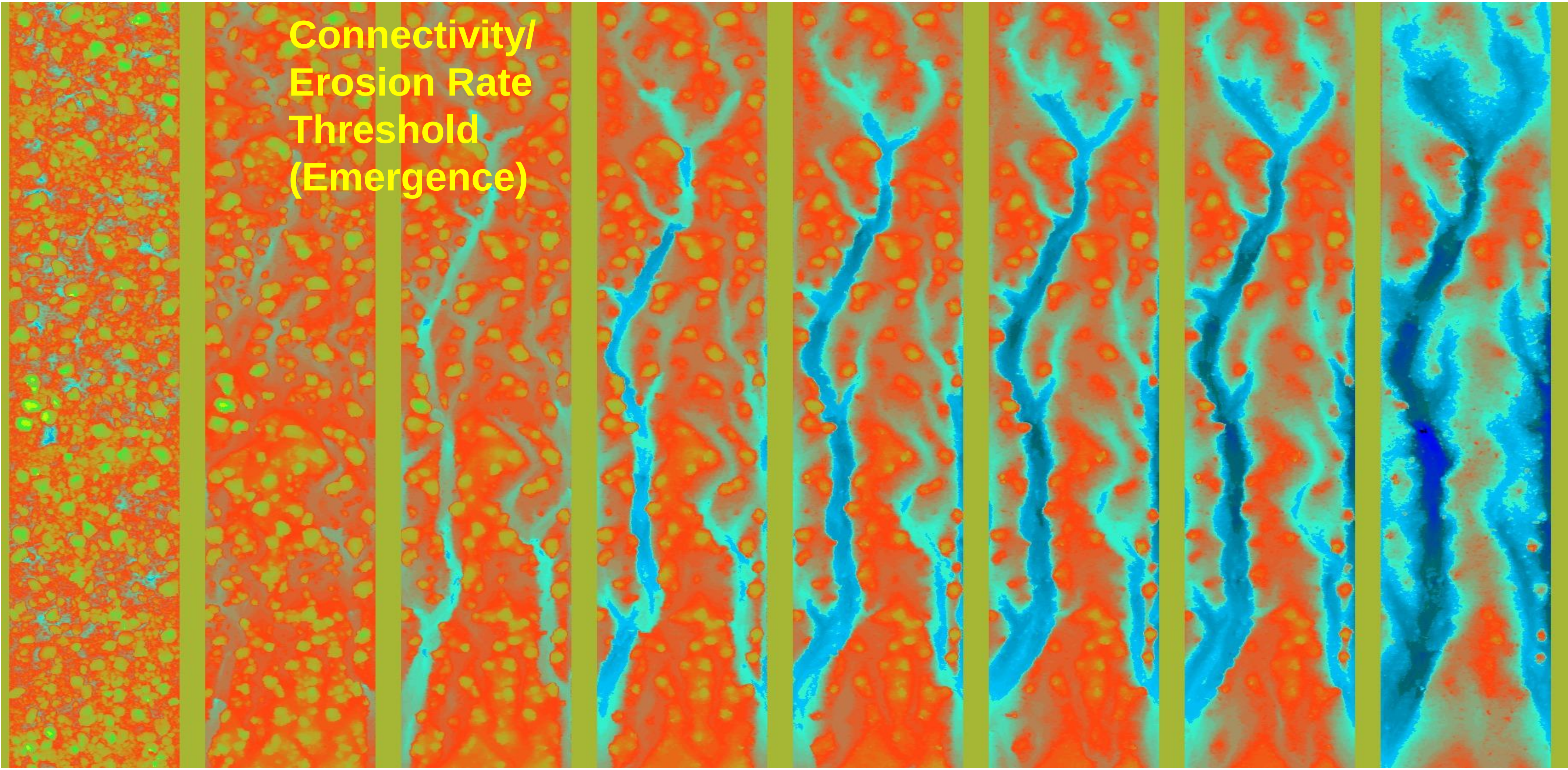
Scale

- The spatial scales at which connections operate range from mm to km x 10^3
- Connectivity is 4 dimensional as connections can occur vertically, as well as down slope, and can change over timescales of hours to millennia
- Connectivity operates underground as well as at the surface
- Not possible at present to model at all scales simultaneously

Surface Connectivity at the Plot Scale

- At the scale of erosion plots (mm to m), the main factors influencing connectivity are microtopographic roughness, stoniness and location of plants and litter.
- Rainsplash and sheetflow modify microtopography over time; so the relationship is ‘complicit’ i.e. circular.

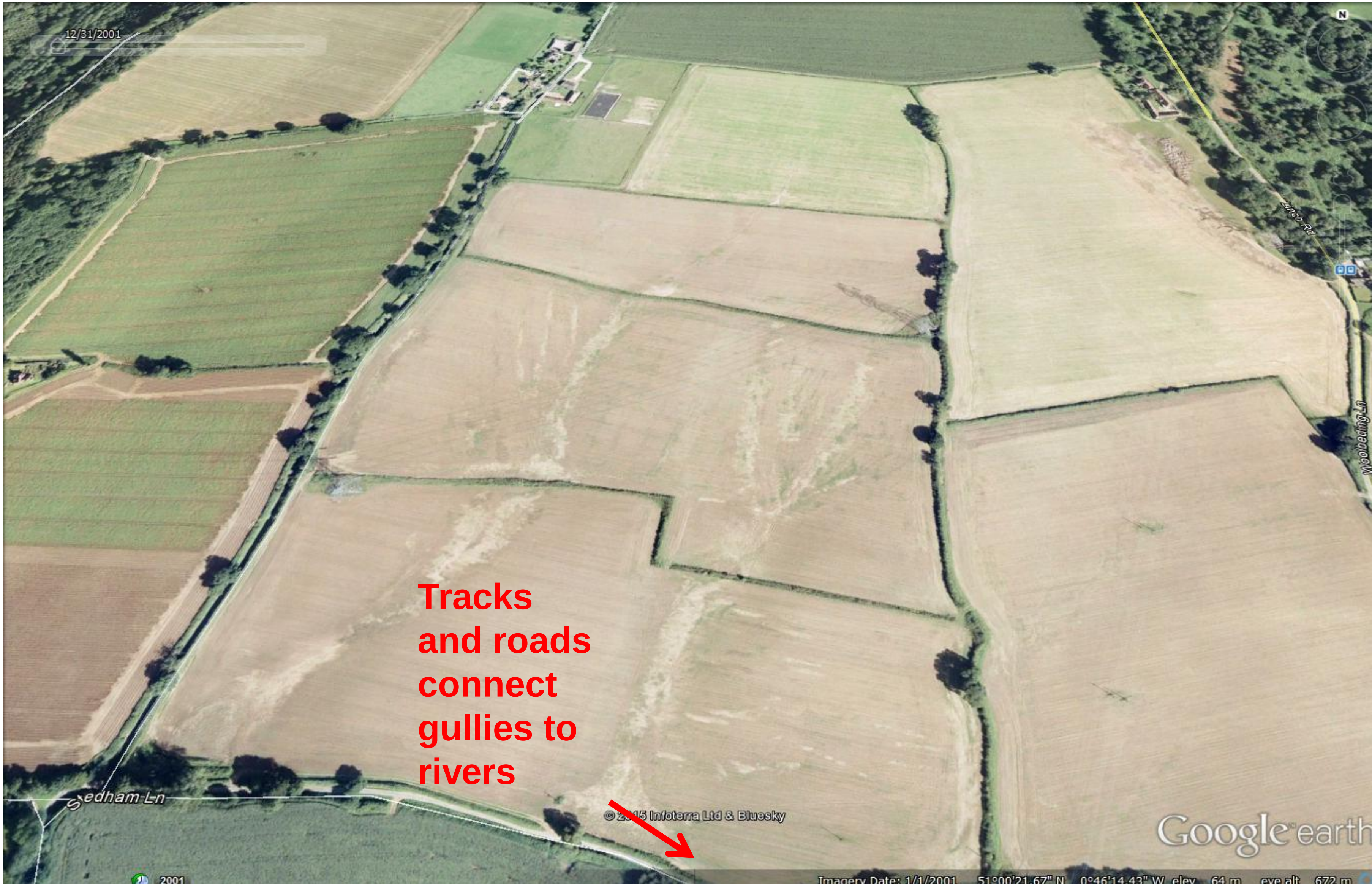
None Low High **Connectivity/ Erosion Rate** Very High



Connectivity at the field scale

At scales of m to m x 10^2), tillage direction and 'wheelings' emerge as concentrated flow pathways

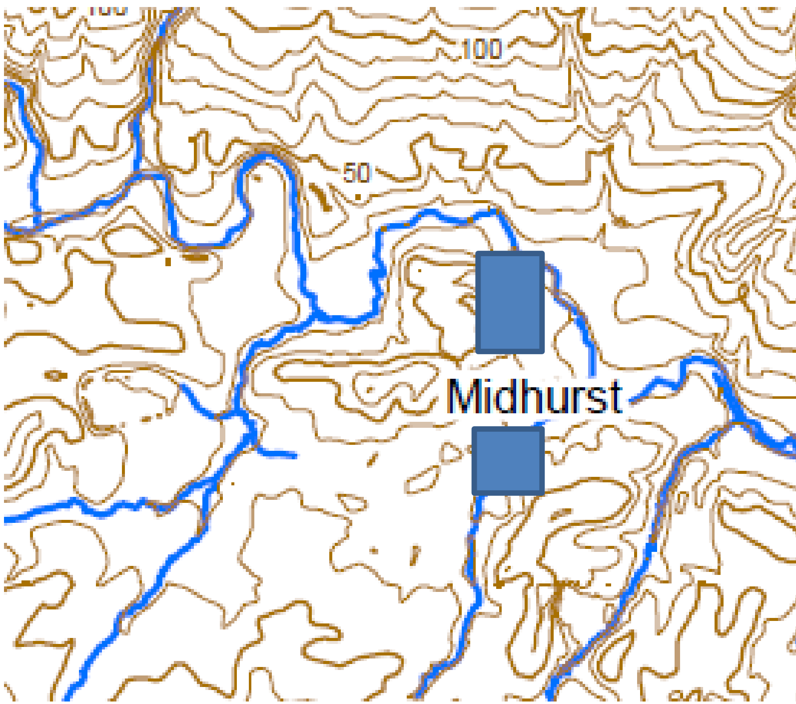
Flow begins by following lines of wheelings, but overtops and follows the line of steepest slope eventually leading to rills and gullies

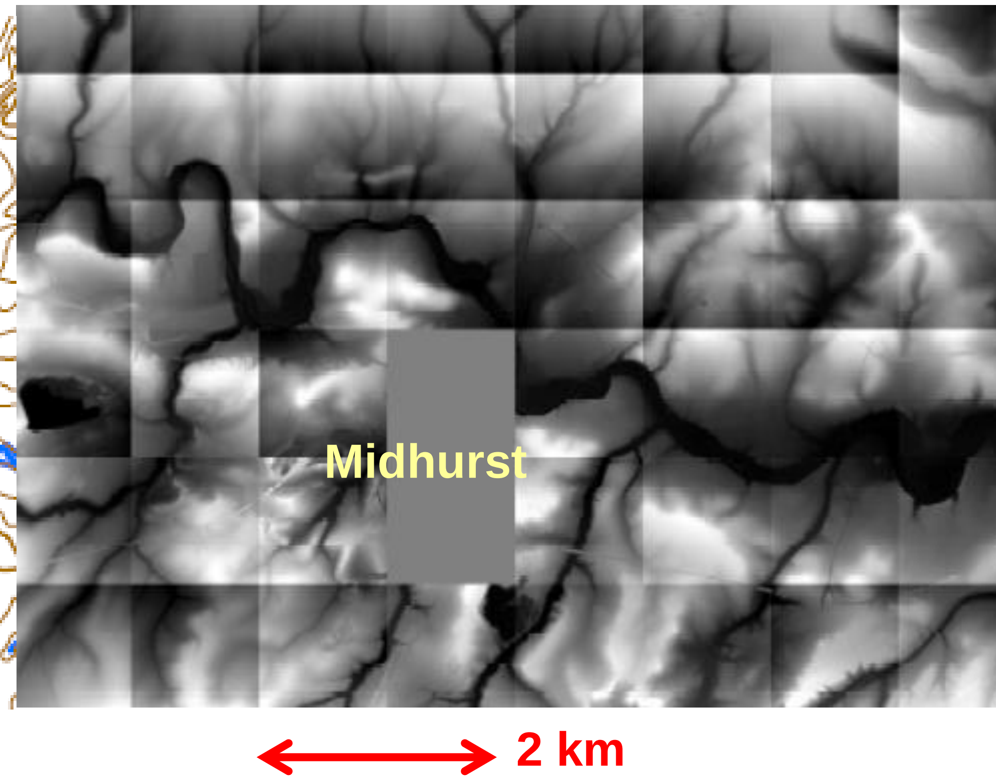


Field scale connections via permeable hedge lines (Jan' 2001, Google Earth image)

Ordnance Survey Contour Map (10 m)

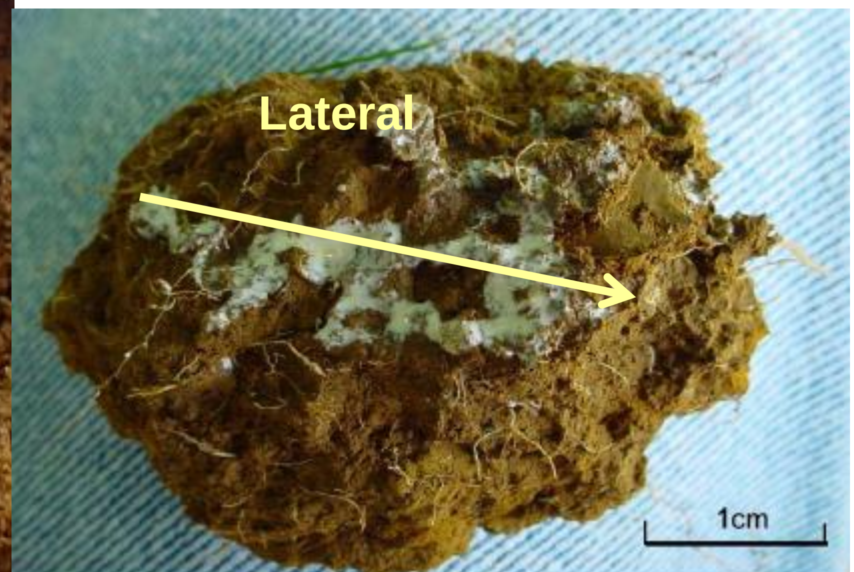
1 m spatial resolution LIDAR Image





Catchment scale connectivity shows significant differences between map and lidar imagery

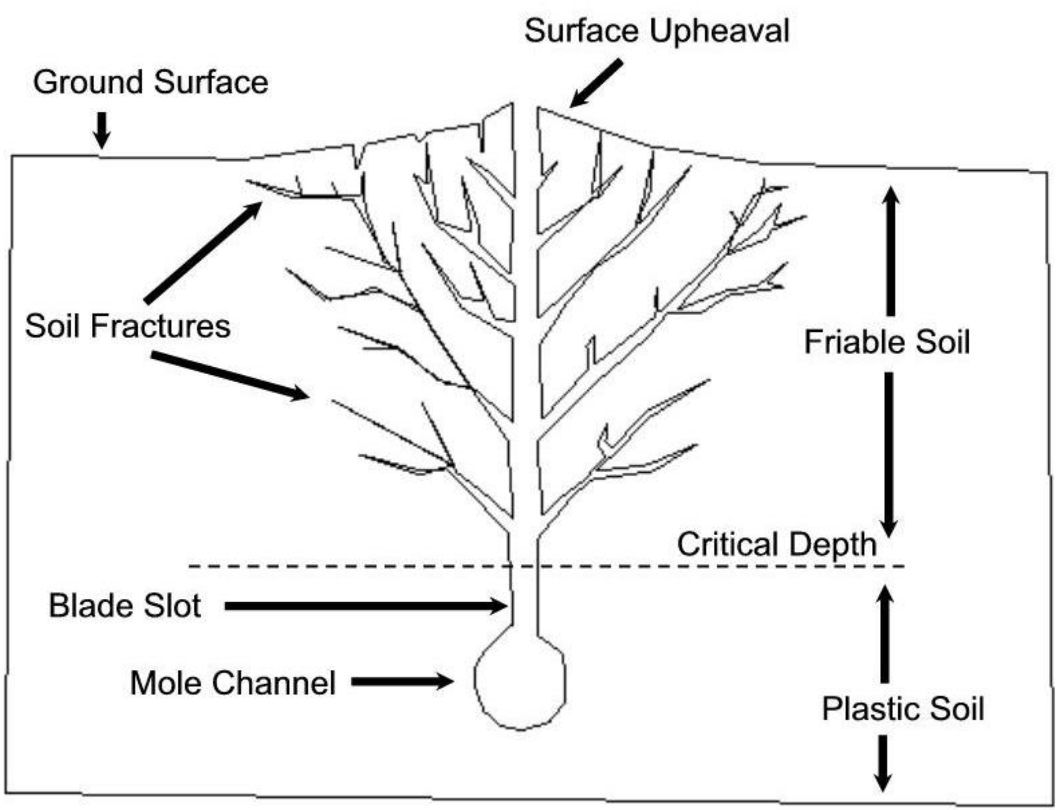
Vertical & Lateral Connectivity through Macropores



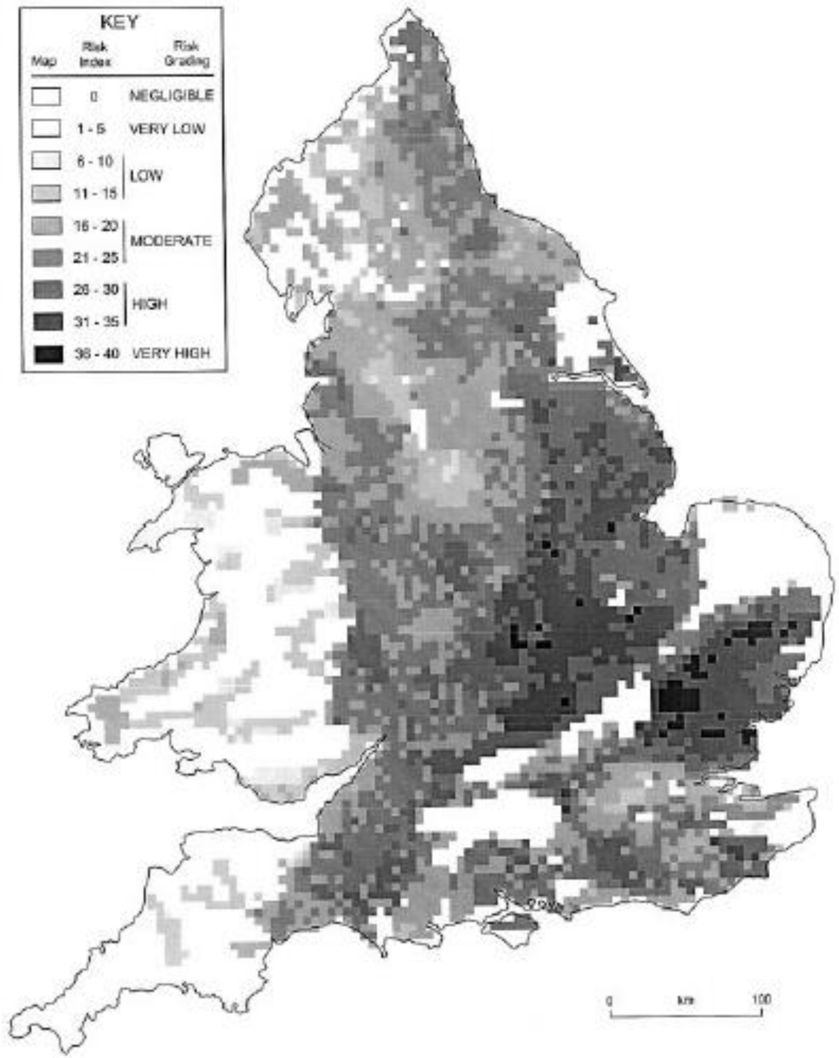
Fluorescein sodium dye and diluted PVA applied to surface of 'Banbury' Soil Association under grassland

Connectivity Varies Seasonally

Mole Ploughing and Land Drainage create new Macropores and increase Connectivity from Macropores to Rivers



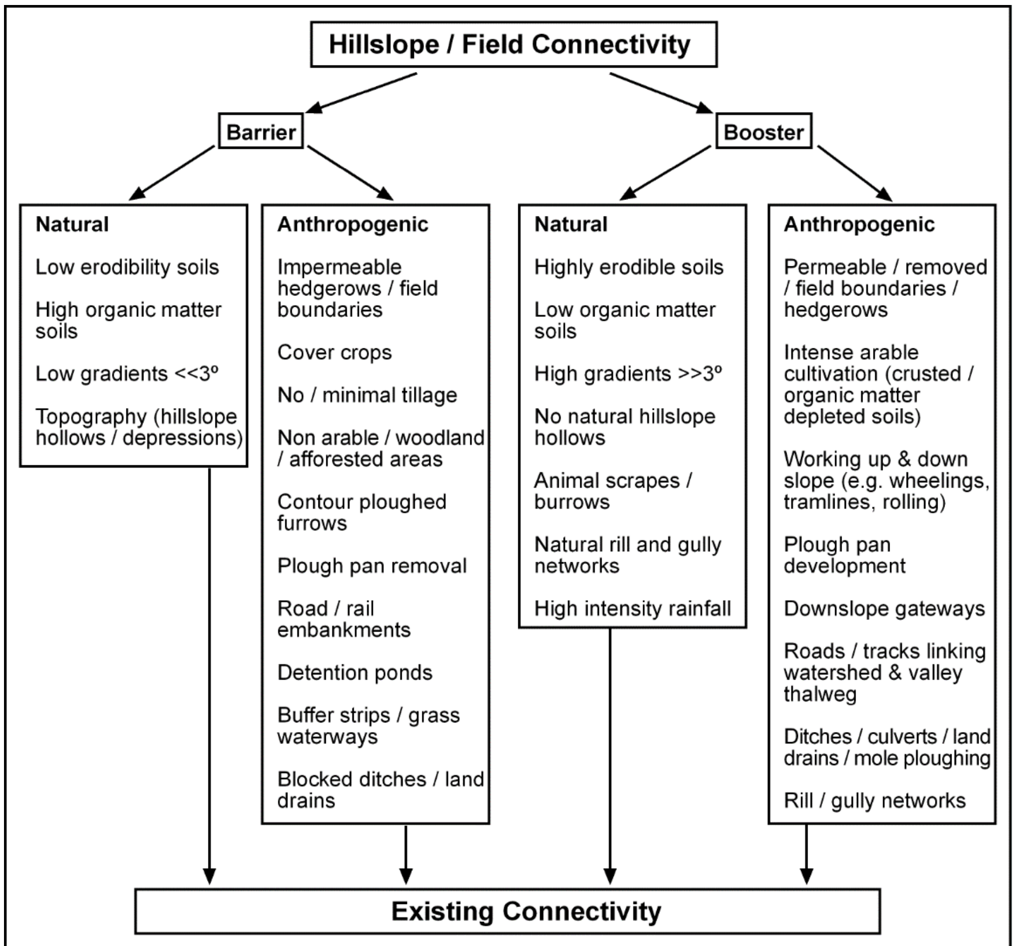
Spatial Risk of Sediment Loss through Land Drains

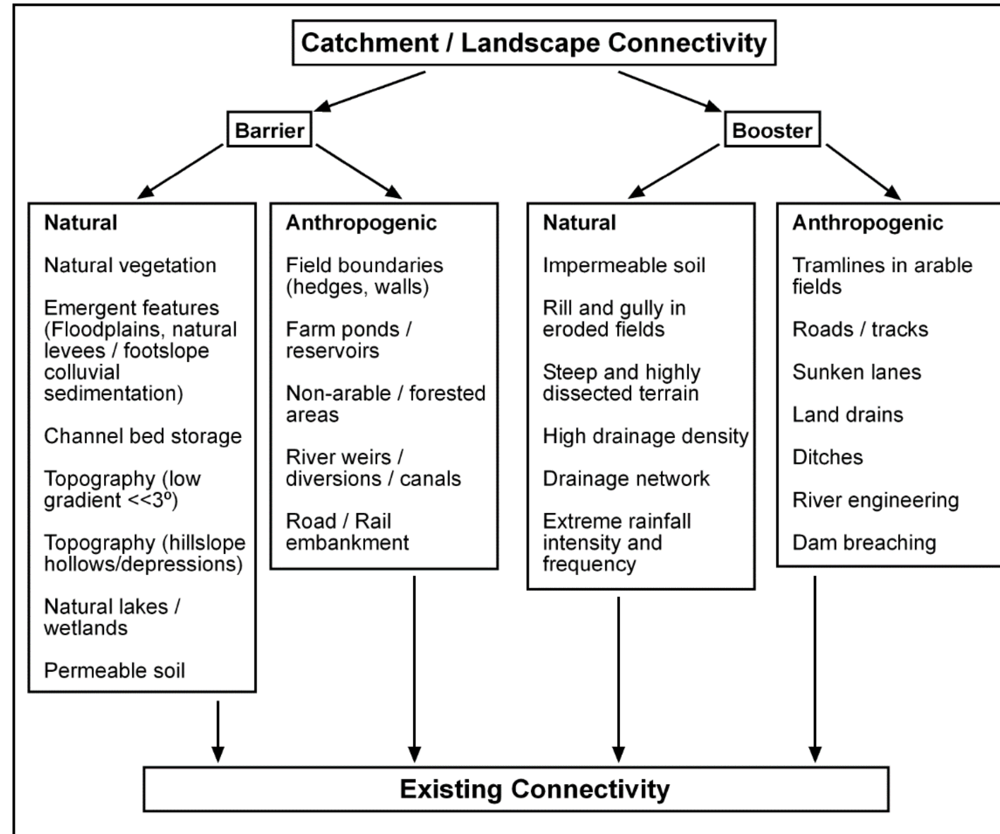


Connectivity at the catchment scale

- At this scale (m x 10^2 to km x 10^4), anthropogenic elements begin to dominate
- Field boundaries may be permeable or impermeable
- Once flow has left the field, ditches, drains, paths and roads form efficient conduits for flow and sediment

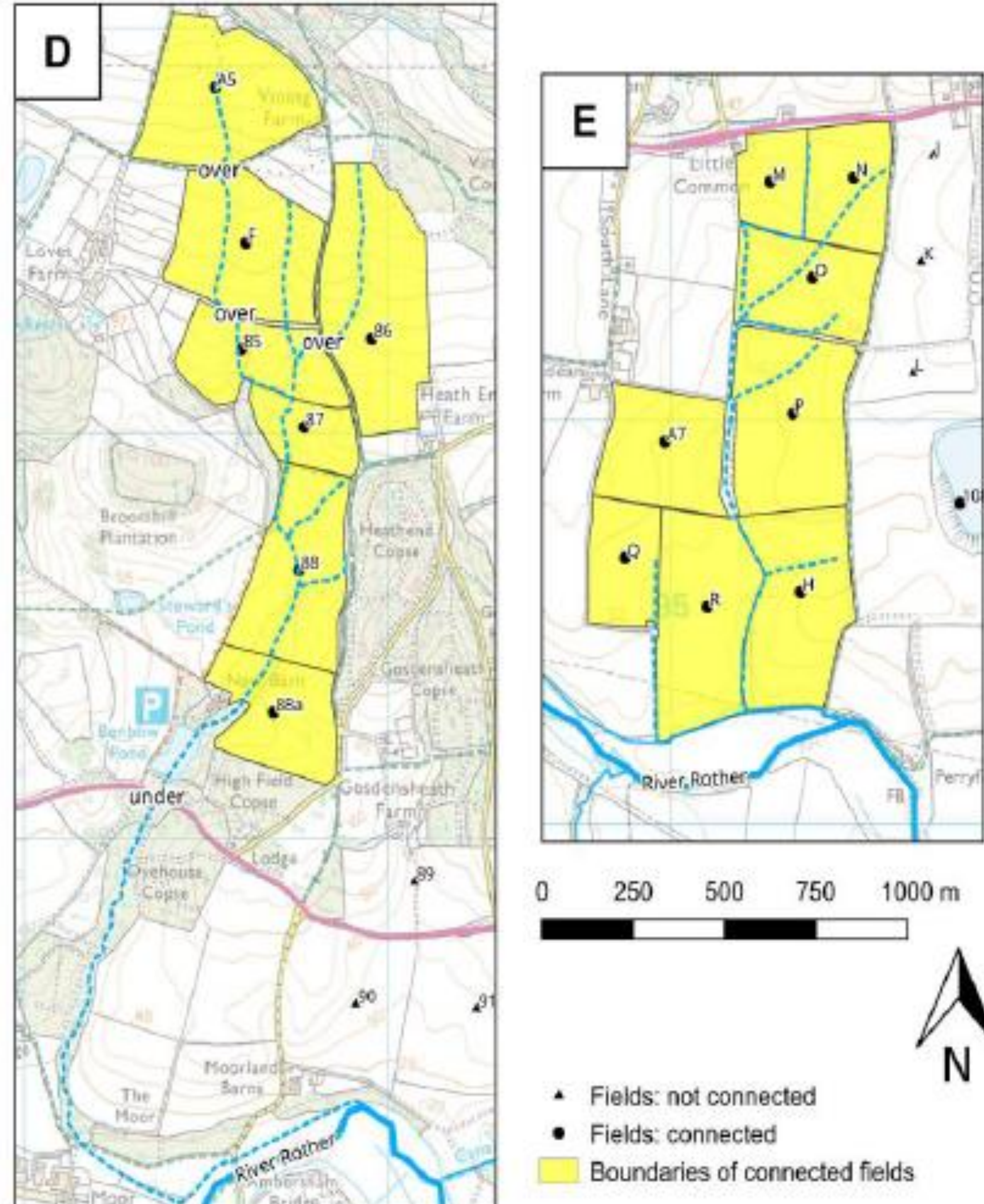
Connectivity in Lowland Agricultural Catchments





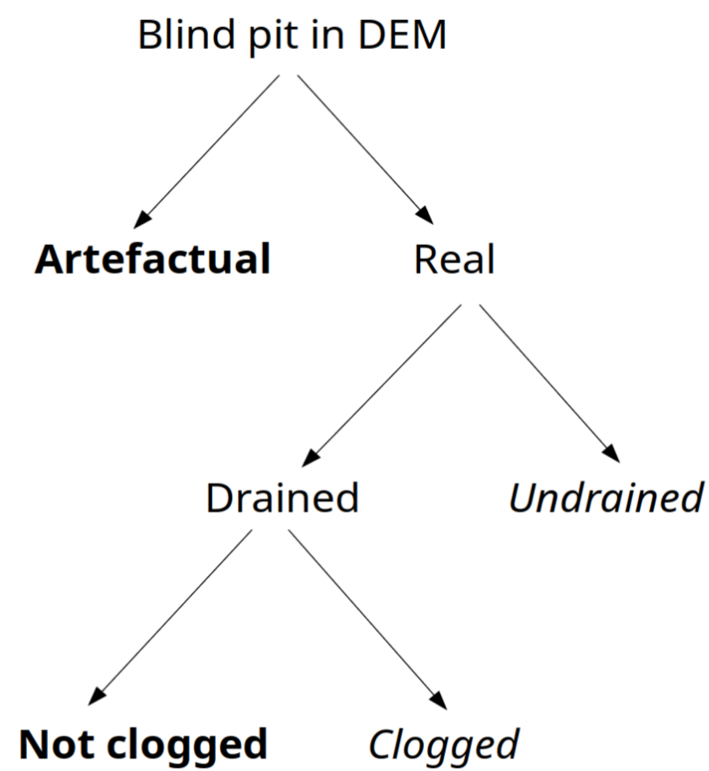
West Sussex Rother

- Boardman identified 165 fields as having a history of erosion (1987-2007)
- Of these, 106 have been connected to the river with runoff travelling via other fields, drains, ditches, roads (especially sunken lanes) or directly to the river
- Remote fields can be better connected than those close to the river



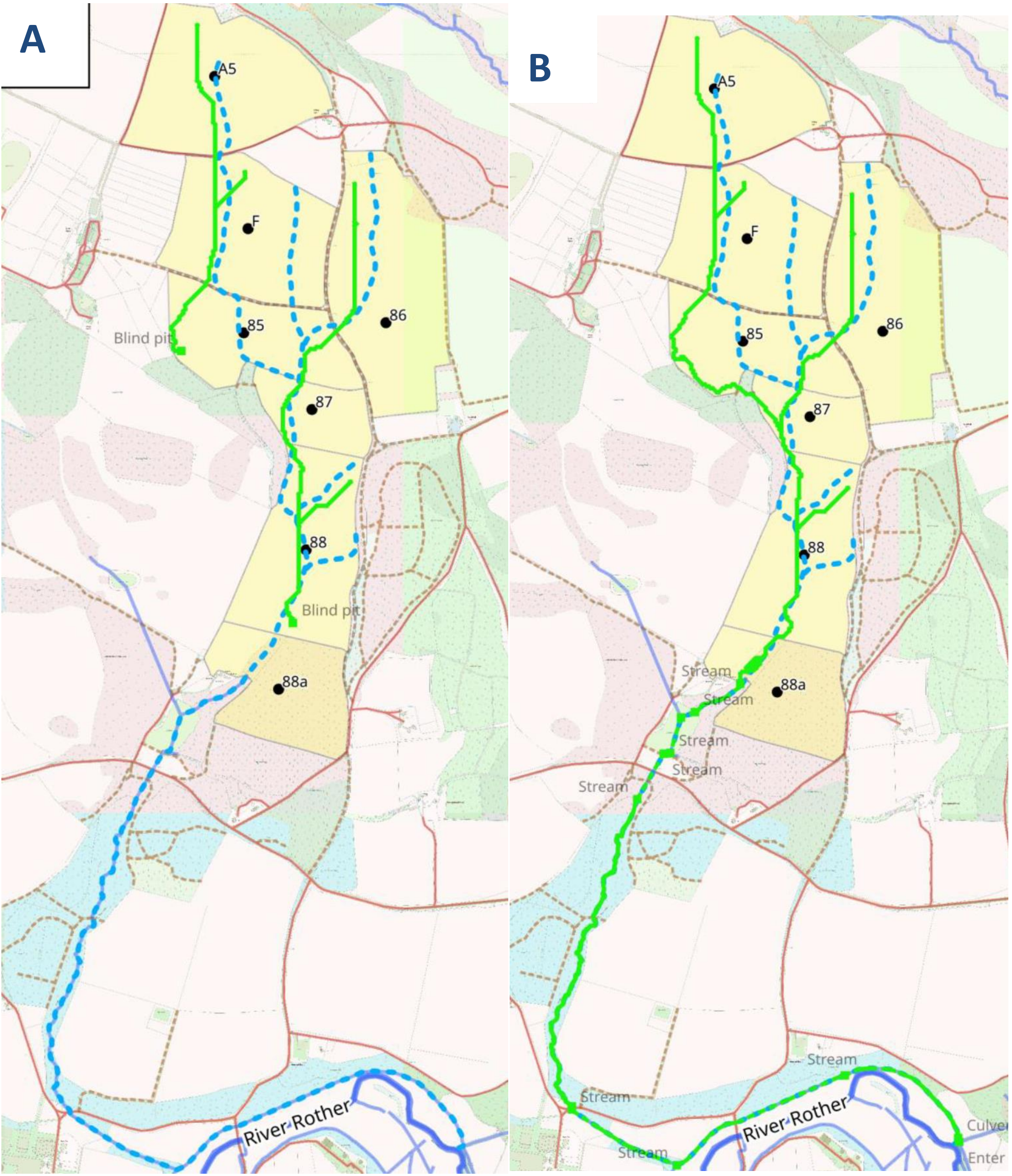
The Challenge: Modelling Connectivity

Blind Pits in DEMs reduce connectivity and could be real or an artefact of the smoothing process used to create them. Currently building a model using 5 m resolution DEM to try and show how landscape elements connect using the fields already mapped



DEM-driven field-to-river flow routes with critical landscape elements that need to be input to the model from field survey

Landscape element	Flow in?	Flow out?	Comment	Effectiveness as a conduit or generator of flow controlled by:	Can be identified from:	Usefulness in preventing runoff and sediment from entering river
Hillslope field, no flow from upslope	N	Y		Land use, gradient, soil surface characteristics	Map	Only if farmer willing to change land use, or to create barriers
Hillslope field, flow from upslope	Y	Y		Land use, gradient, soil surface characteristics	Map	Only if farmer willing to change land use, or to create barriers
Field boundary, fully permeable	Y	Y	Flow of any volume can cross	Nature of boundary	Field survey essential	Could be blocked
Field boundary, semi-permeable	Y	Y	Only flow above some threshold volume can cross	Nature of boundary	Field survey essential	Could establish grass buffer strip
Ditch	Y	Y	Not usually marked on maps	Whether recently cleaned of sediment and vegetation	Field survey essential	Not useful
Stream	Y	Y	Marked on map		Usually on map	Not useful
Flow over road or track	Y	Y		Very effective	Field survey essential	Could be dammed (but this could lead to flooding)
Flow under road or track	Y	Y		Very effective	Field survey essential	Could be blocked (but this could lead to flooding)
Flow along road or track	Y	Y		Very effective	Field survey essential	Could be dammed, need to prevent flow onto road
Flood plain (or terrace) field	Y	Y	Low gradient, flow enters from upslope creating rills or ephemeral gully	Land use, soil surface characteristics	Map	Establish grassed area along former ephemeral gully
River	Y	N		N/A	Map	N/A



Observed and modelled Connectivity

A) DEM generated flow paths only

B) DEM generated flow paths with flow-landscape element interactions explicitly considered (including filling of some blind pits)

While not a perfect simulation of flow paths the model provides a much better representation of connectivity between field and river than the DEM alone

Observed flow lines

Modelled flow lines

Conclusions

Connectivity varies with scale

Many landscape elements needed to fill bind pits in DEMs need to be field derived

Providing this information in a developing model significantly improves models of connectivity at the field / hillslope and catchment / landscape scale

The only way of capturing the complexity of connectivity is to map connections using field surveys – preferably when it is actually raining hard