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The Suitability of Using Least Cost Path Analysis in the Prediction of Roman Roads in the Highland and Lowland Zones of Roman Britain

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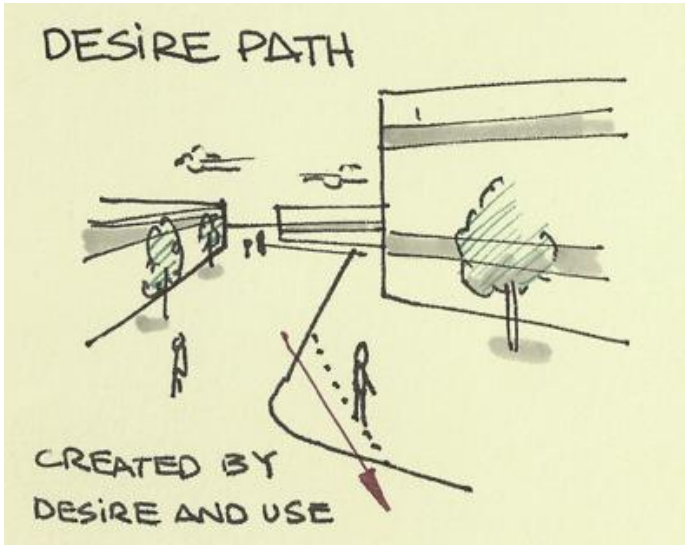
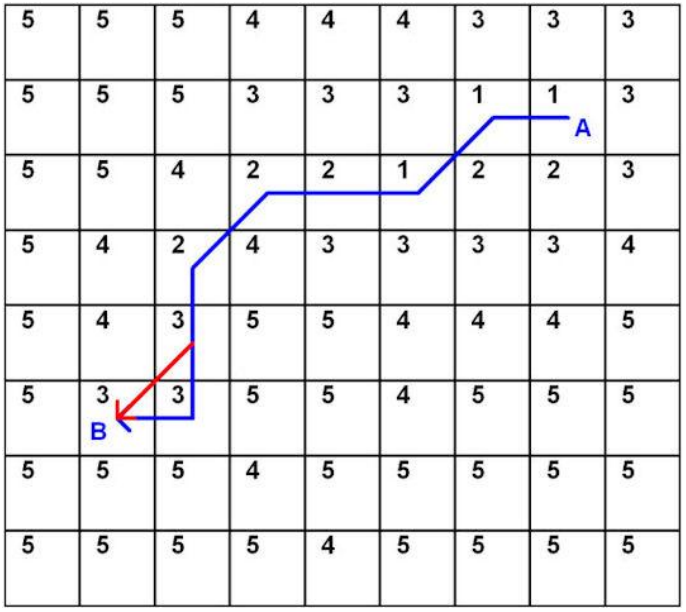
What is Least Cost Path Analysis?

- Based on the Principle of Least Effort (Zipf, 1949), which assumes that **humans will naturally choose the path of least resistance when travelling in a landscape**
- LCP analysis computes the **optimal route between two locations** that minimises the effort needed to cover the distance
- Most commonly computed using **Dijkstra's algorithm** (Herzog and Posluschny, 2011)
- Widespread use of LCP analysis to **reconstruct ancient roads** (e.g., Verhagen and Jeneson, 2012), and **identification of factors governing the construction of known roads** (Bell and Lock, 2000)





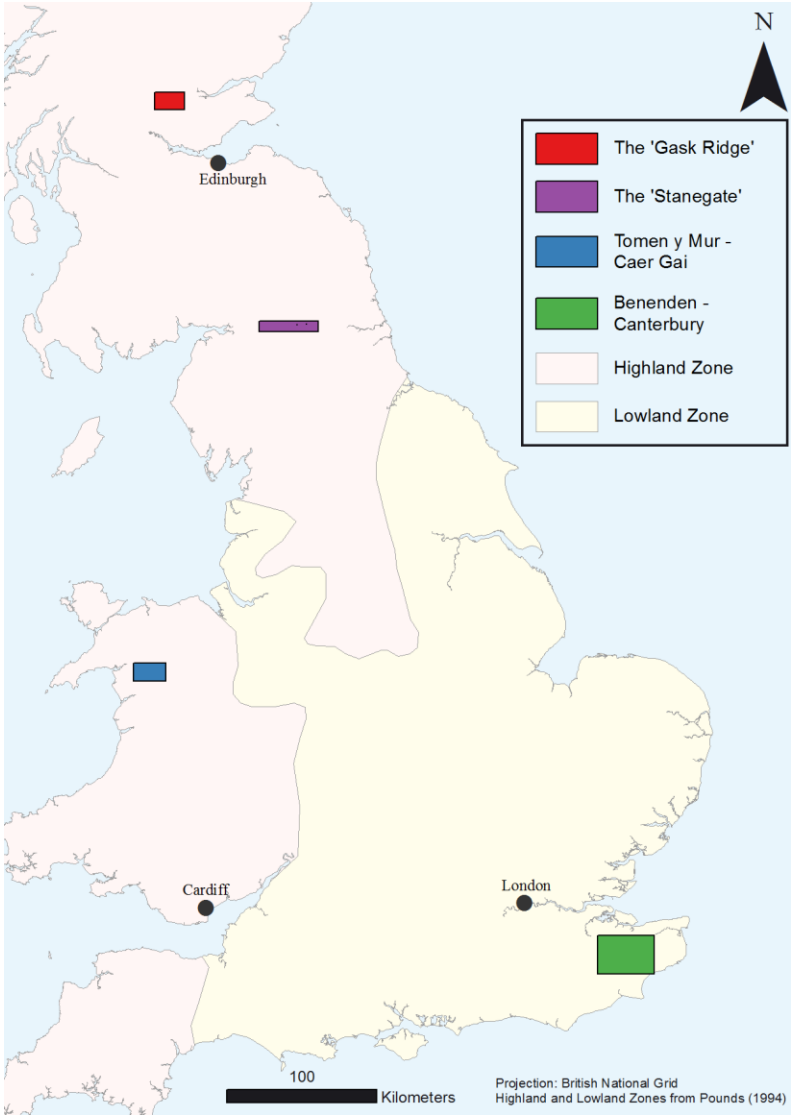
Herzog, 2013a, p.1

Why Roman roads in Britain?

Long history of interest in the study of Roman roads in Britain e.g., Codrington (1918) and Margary (1973)

Roman Britain road network is particularly well understood (Orengo and Livarda, 2016)

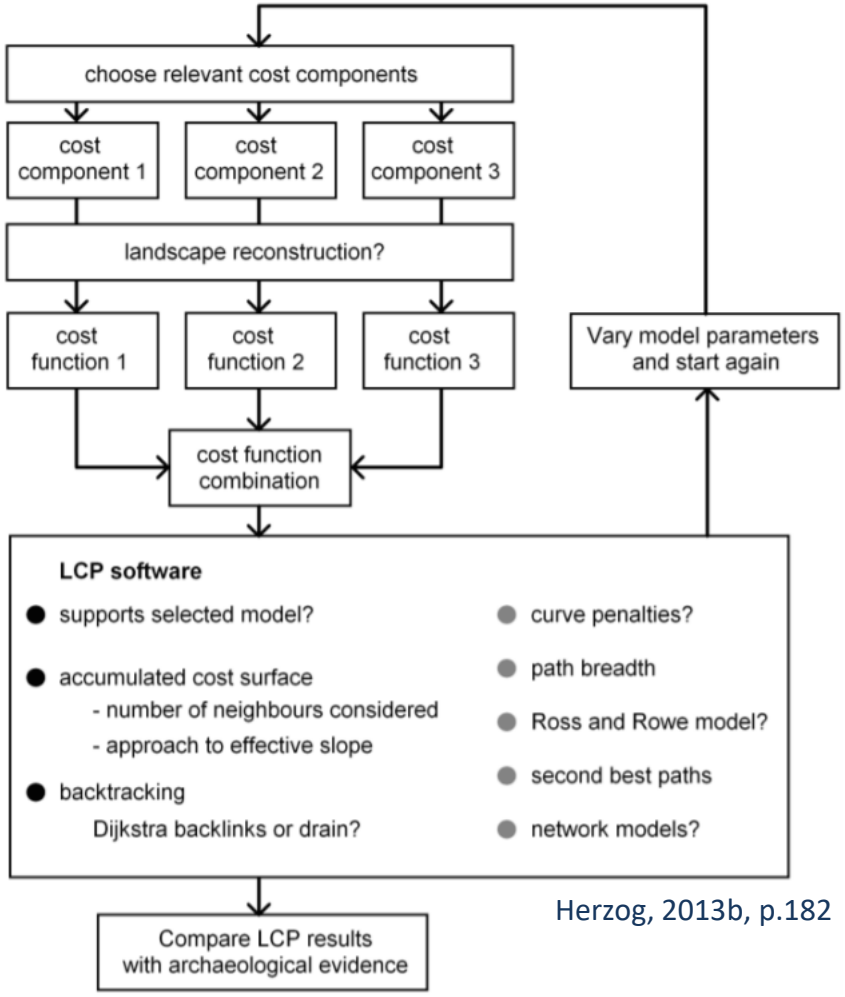
- Roman Britain is often divided into two zones:
  - **The Lowland zone**
    - **large areas of flat land in the South and East**
    - Road network developed to provide communication for expanding civilian economy
  - **The Highland zone**
    - **steep sloped and mountainous North and West**
    - Road network facilitated quick and effective movement of troops and supplies
- LCP analysis thought of as environmentally deterministic, as **cultural or social variables are difficult to model**
- **Hypothesised that LCPs computed in the Highland zone will predict the location of Roman roads more accurately than LCPs in the Lowland zone**



Methodology

Methodological Contention?

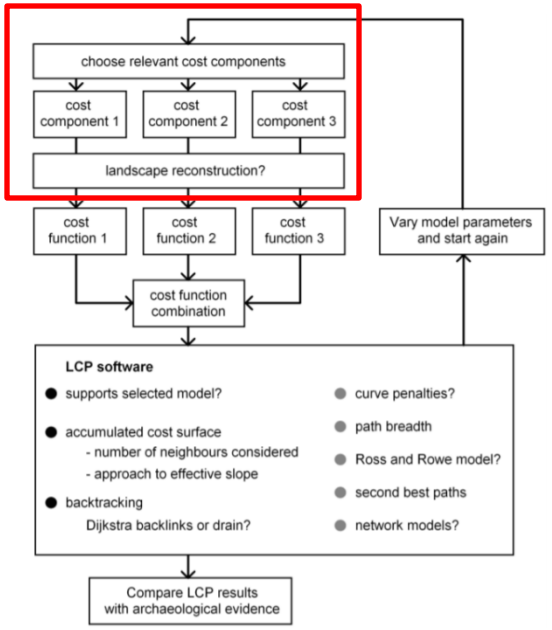
- LCP analysis represents a **well established** methodology within archaeological GIS (Rahn, 2007)
- The application of LCP techniques are **inadequately applied** in some cases (Herzog, 2013a)
- Wide variety of parameters used to calculate LCPs is a **"sign of immaturity in the field"** (van Leusen, 2002, p.6.5)
- LCP **validation** is the most important component of LCP analysis , however this is **uncommon** (Vermeulen, 2006)



Herzog, 2013b, p.182

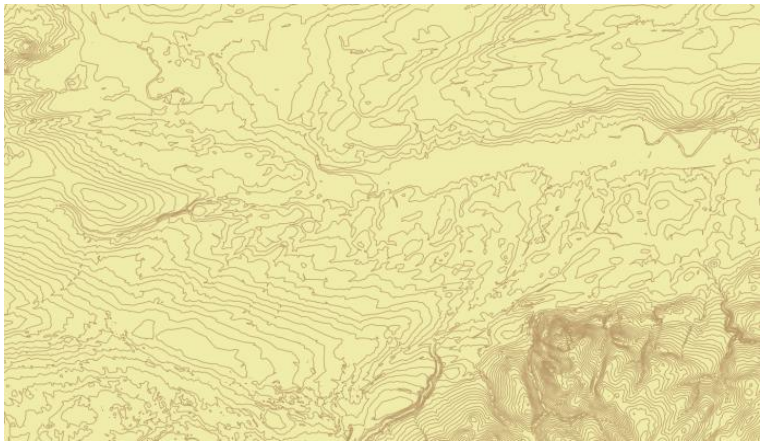
Methodology – Cost Components

Cost components numerically express the difficulty of moving between individual cells in a raster grid



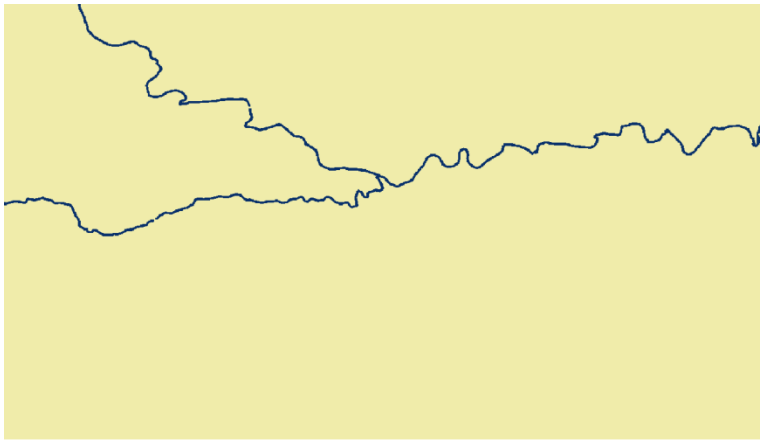
Herzog, 2013b, p.182

DEM (slope) – OS Terrain 5m

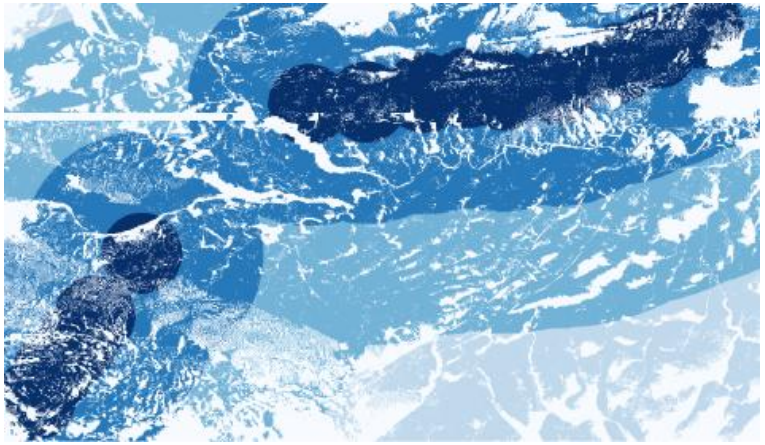


Nearly all archaeological LCP studies are based on slope (Herzog, 2013b)

OS River Network

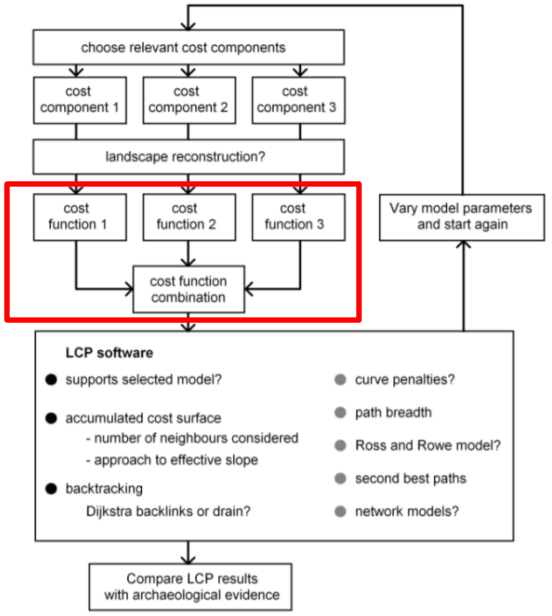


Higuchi viewshed



Methodology – Cost Functions

Cost functions allow for the calculation of the cost of each move from a raster cell to its neighbour



Herzog, 2013b, p.182

Tobler's Hiking Function (Tobler, 1993) - **Time-based**

- Cost = 6 ∗ exp(-3.5 * abs(S + 0.05))

Modified Hiking Function (Márquez-Pérez et al., 2017) - **Time-based**

- Cost = 4.8 * exp(−5.3 × abs((S * 0.7) + 0.03))

Sixth Degree Polynomial (Herzog, 2010) - **Energy-based**

- Cost = 1337.8 S^6 + 278.19 S^5 - 517.39 S^4 - 78.199 S^3 + 93.419 S^2 + 19.825^S + 1.64

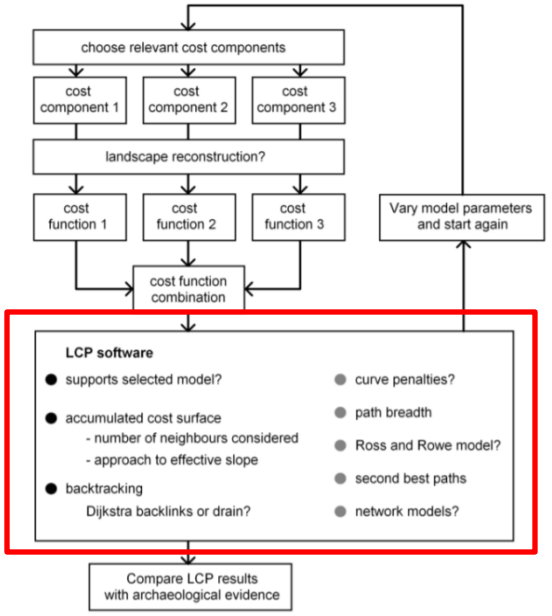
*Where S are Slope values

Due to the accuracy of LCPs being sensitive to the algorithm used, multiple cost functions should be compared (Mlekuž, 2014)

Cost Functions are arguably the most important component of a successful LCP analysis (Kantner, 2012)

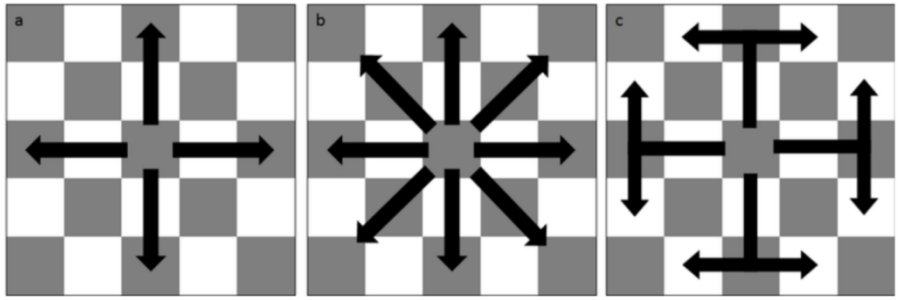
Methodology – LCP Software

The implementation of LCP analysis into GIS software has led to many studies using default settings, unaware of methodological issues (Herzog, 2014b)

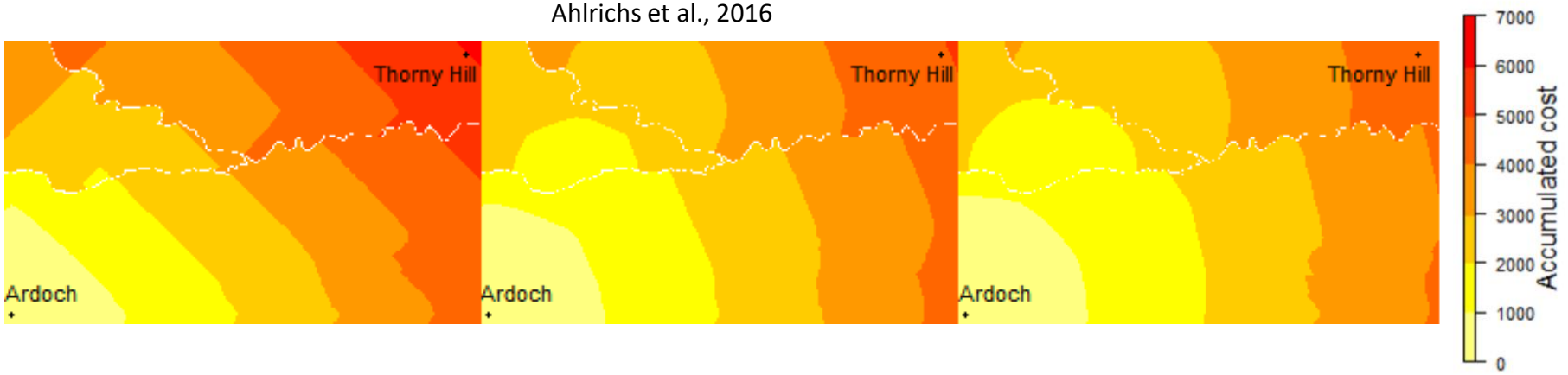


Herzog, 2013b, p.182

- **e.g., Number of neighbouring cells considered**



Ahlrichs et al., 2016

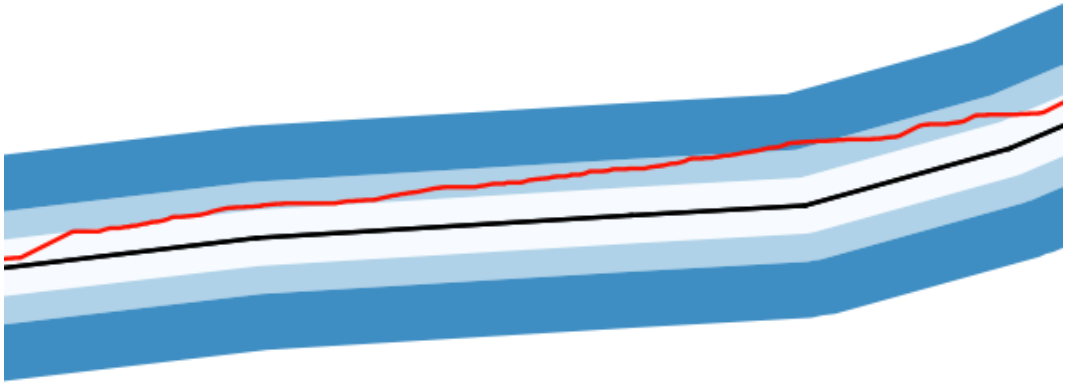


Use of gdistance (R package) to overcome limitations with software such as ArcGIS and GRASS

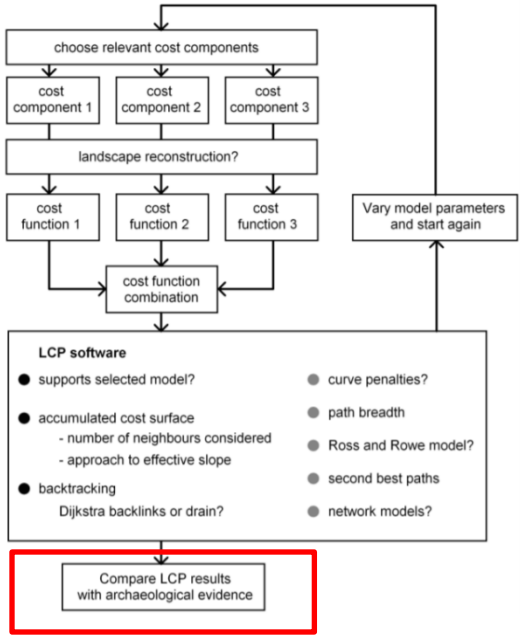
Methodology – LCP Validation

Although there is no established method (Kantner, 2012), the best option is to compare the LCP results to remnants of old routes (Herzog, 2014a)

- **Validated by determining the percentage of the LCPs within buffer distances from the known Roman roads**



- **Proposed the use of Flow maps as a way to visualise LCPs and understand the distribution of accuracy**



Herzog, 2013b, p.182

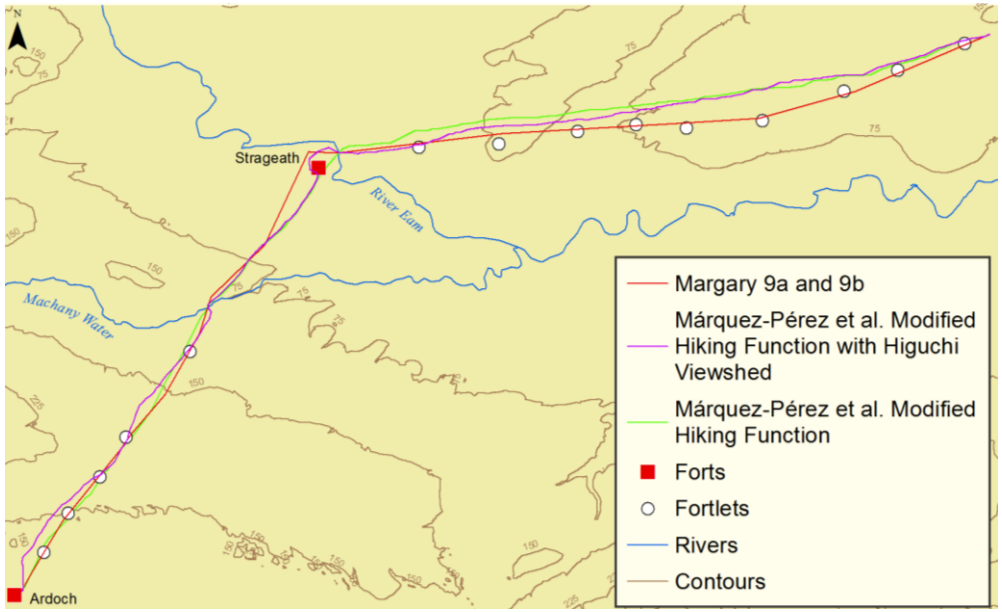
Without validation, LCP results are “mere guesswork” (Herzog, 2013b, p.205)

Results – Highland zone

Cost function comparison

- **Sixth Degree Polynomial (energy-based) least accurate at predicting the location of the Roman road in the Highland zone study area**

- **Findings agree with Livingood (2012), who recommended the use of time based cost functions, as historical accounts were recorded in time rather than energy expenditure**



Cost Function	Within 250m (%)	Within 500m (%)	Within 1000m (%)
Sixth Degree Polynomial	56	67	100
Tobler's Hiking Function	64	98	100
Modified Hiking Function	64	98	100

Higuchi viewshed incorporation

- **Increased accuracy of LCP**

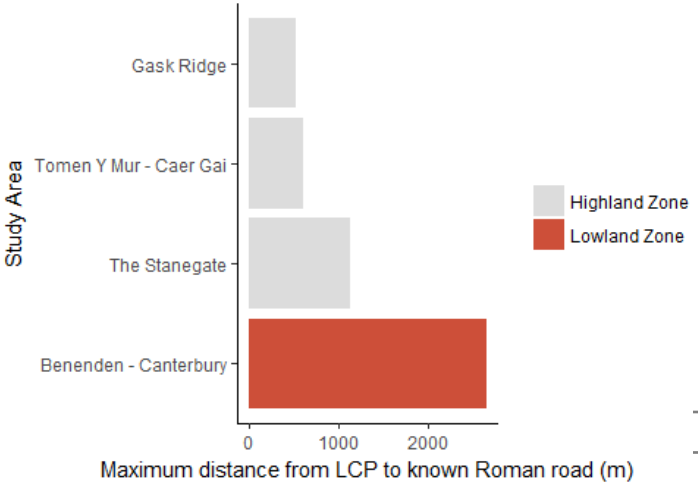
- **Further strengthens the conclusion that the road location was dictated by the need to control the road**

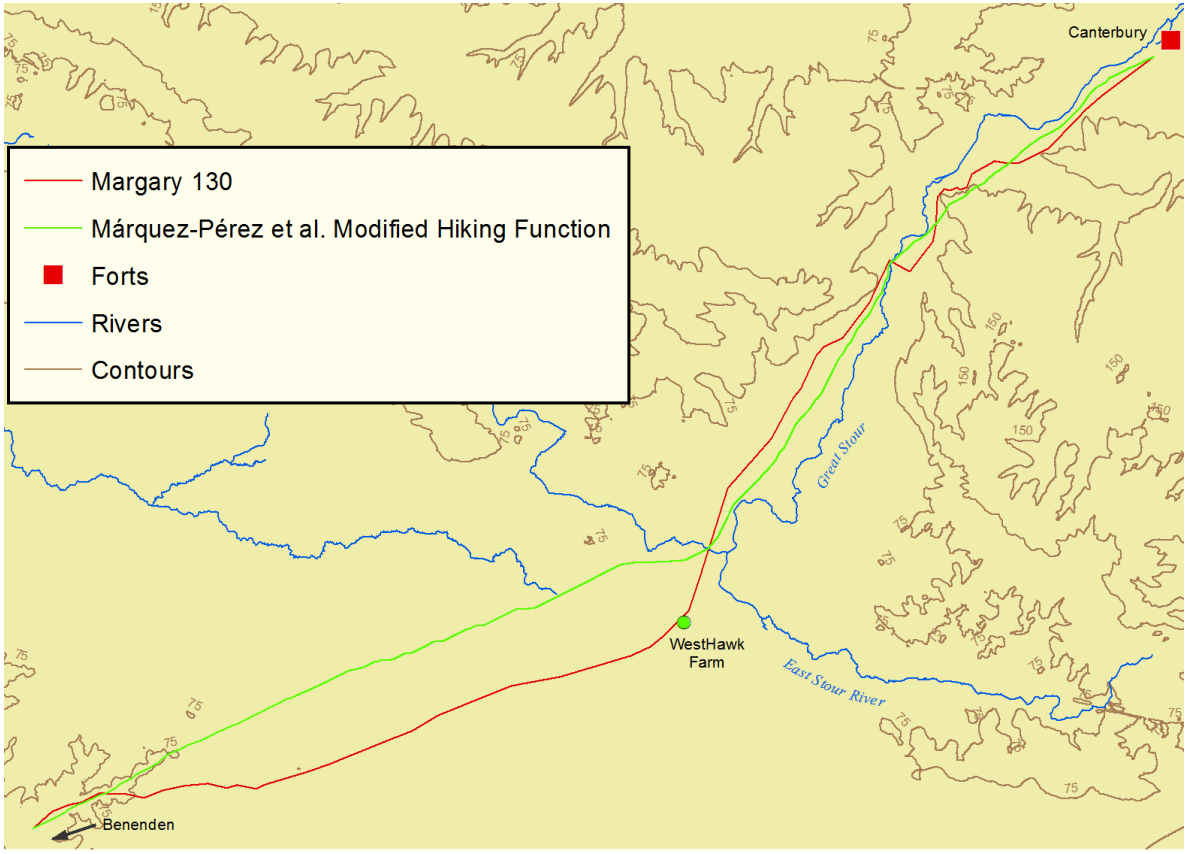
Cost Function	Within 250m (%)	Within 500m (%)	Within 1000m (%)
Modified Hiking Function	64	98	100
Higuchi Viewshed inclusion	77	98	100

Results – Lowland zone

Environmental Determinism

- **LCP analysis predicts the Lowland zone Roman road less well**
- **Limited by inability to model social or cultural phenomena adequately**





Cost Function	Within 250m (%)	Within 500m (%)	Within 1000m (%)
Lowland zone study area	31	50	62

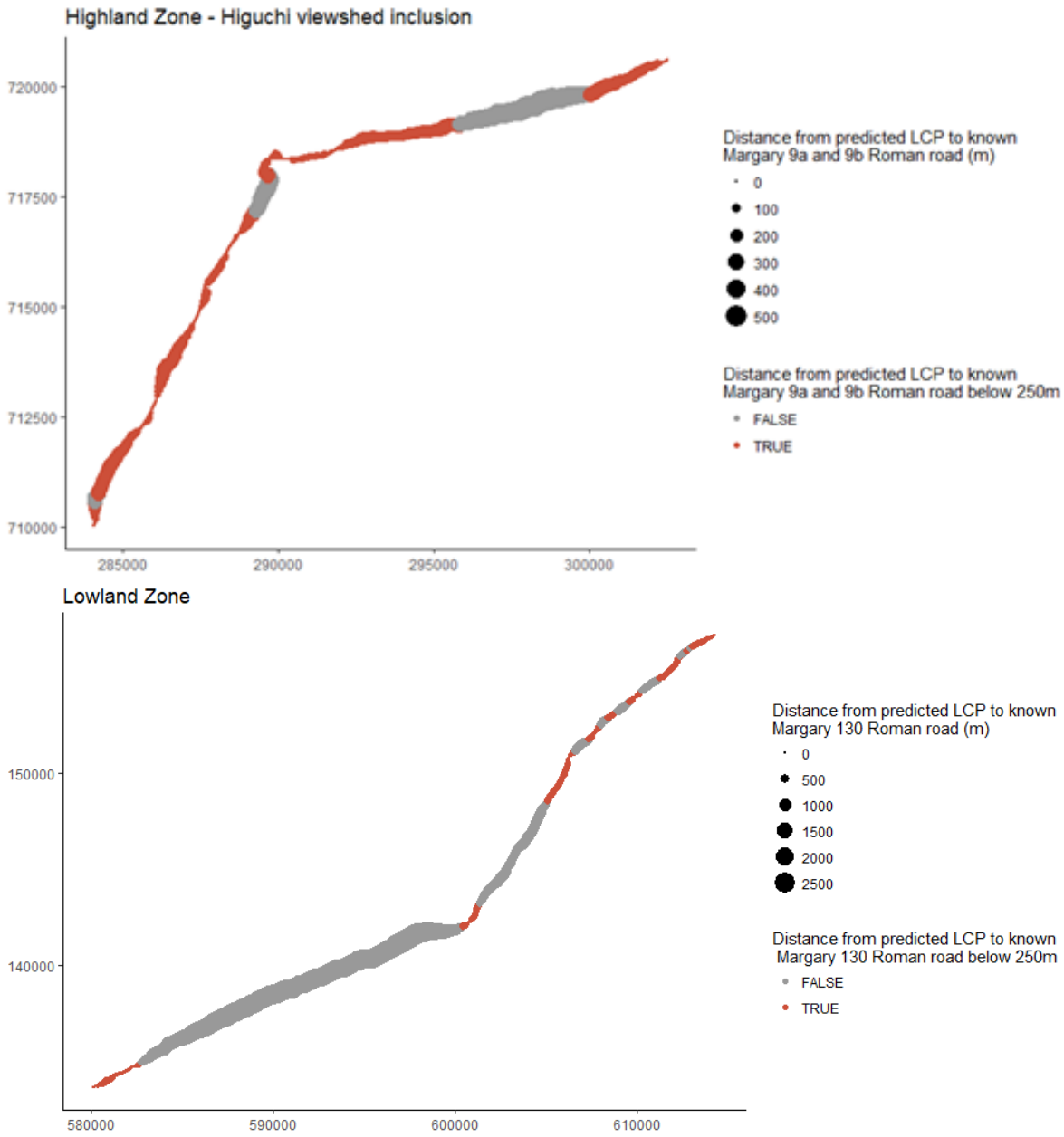
Cost Function	Within 250m (%)	Within 500m (%)	Within 1000m (%)
Highland zone study area	77	98	100

Results – LCP Visualisation

Percentage of LCP from known Roman roads is a coarse representation of the accuracy

Flow maps

Line thickness denotes distance from LCP to known location of Roman roads



Significance

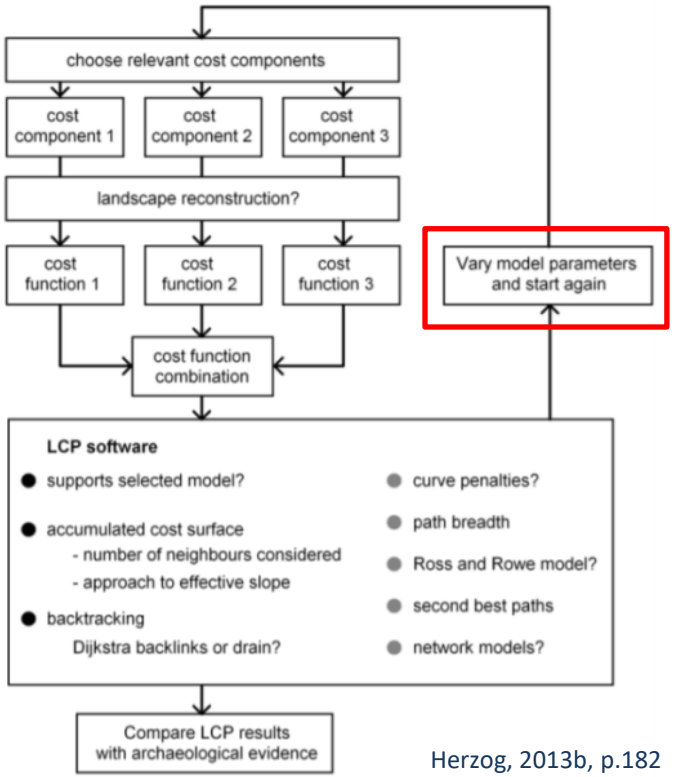
	Contribution to the study of LCP analysis
• Many studies use default settings to calculate LCPs, unaware of alternative and methodological issues (Herzog, 2014b)	• Use of gdistance to allow for greater flexibility in the calculation of LCPs
• Little work in evaluating which cost function best models real human movement (Kantner, 2012)	• Identified the Modified Hiking Function as an alternative to the widely used Tobler's Hiking function
• Visibility analysis is complex, with many methods not representing the sensory experience	• Higuchi viewsheds effective at determining whether the need for visibility dictated the location of Roman roads
• Current validation methods coarse and lack interpretability (Ali, 2003)	• Flow maps allow for greater exploration of LCP results, and clarity when comparing multiple cost functions
• LCP analysis is thought of as being environmentally deterministic, and overemphasises environmental factors on cultural activity	• Unless social factors of the study area in Roman Britain are well known, the use of LCP analysis is recommended for the Highland zone

Future Developments

- Incorporate artefacts into LCP calculation (e.g., distance from tombs, milestones)

- Combine LCP analysis with network analysis techniques in order to describe the patterns of communication of Roman roads in Roman Britain

- **The use of Approximate Bayesian Computation to simulate multiple parameter combinations in order to generate LCPs that best match known paths**



Herzog, 2013b, p.182

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Thank you

Any questions?

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