Assessment of structural connectivity of a forested landscape in Poland using graph theory approach

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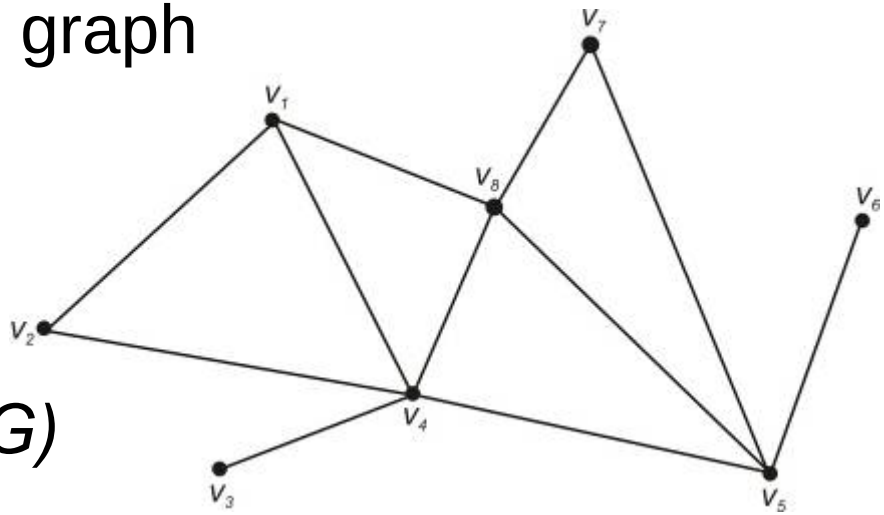
Landscape connectivity

- dispersal capability of species among habitats
- a crucial ecological process
  - maintains genetic diversity
  - prevents decline of populations
  - desirable quality of protected area networks
- a strength of linkages between remaining fragments of habitat
- function of habitat size, continuity and inter-habitat distances
- scale-dependant property
- structural and functional

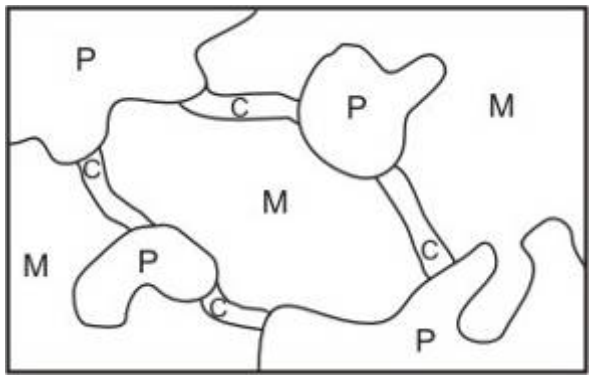
Graphs and graph theory

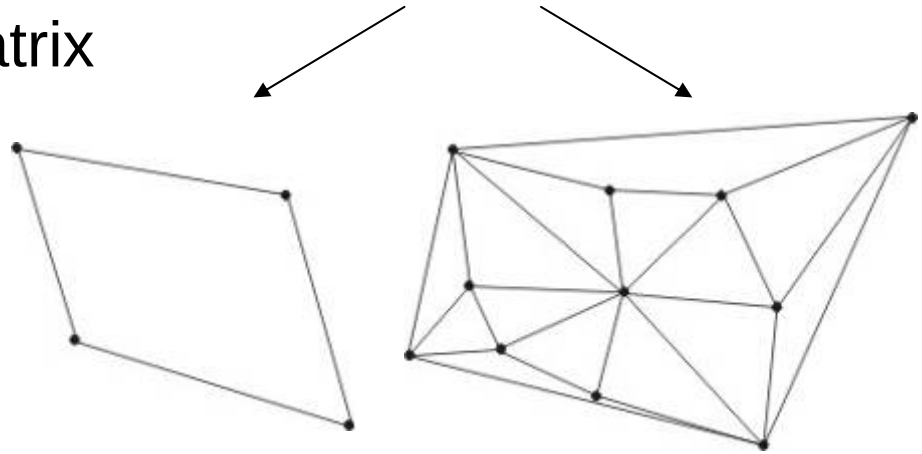
- graph *G*
  - set of nodes [vertices] *V(G)* and edges *E(G)*
  - each edge $e_{ij} = v_i v_j$ connects nodes v_i and v_j
- walk, path and tree in the graph
- connected graph
  and its components
- node-connectivity *κ(G)*
  and edge-connectivity *λ(G)*
- diameter *d(G)*



Graphs in landscape connectivity research

- landscape as a network and its graph representation
  - habitat patches as nodes and linkages between them as edges
  - patches, corridors and matrix as nodes; edges show adjacency

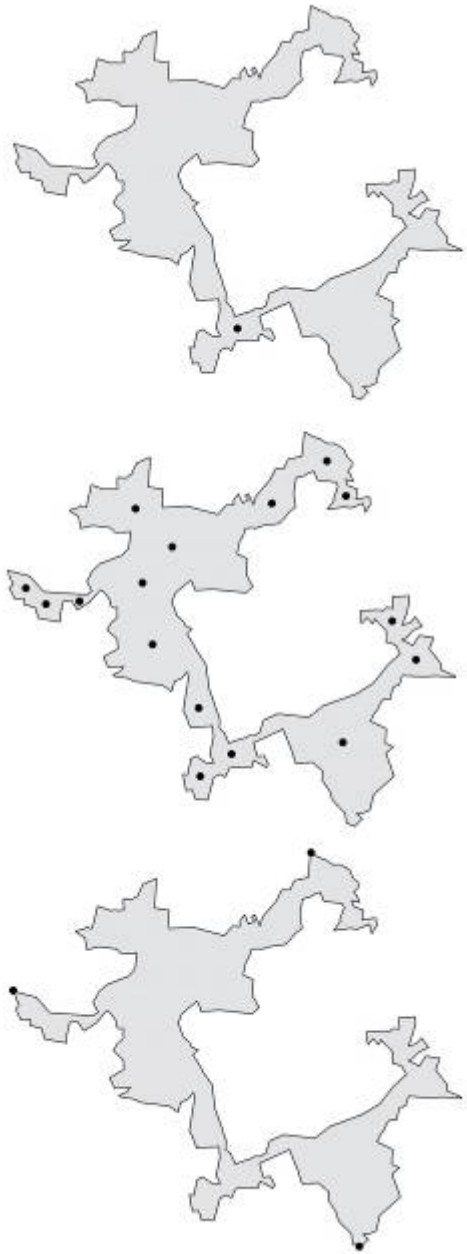




Landscape as a graph: various options

- polygon-to-point transformation
  - patch-centroid method
  - multi-point patch method (local distance maximum identification)
  - selected points of patch edges

- distances between nodes
  - Euclidean distances
  - cost distances

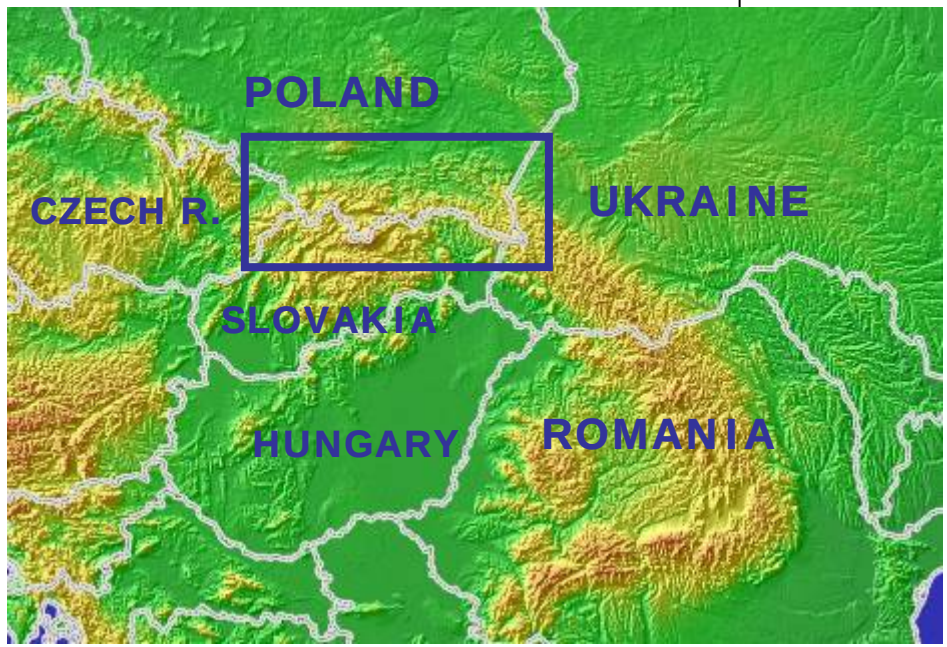


Aims of the work

- to compare various methods of graph construction in the context of landscape connectivity
  - polygon-to-point transformations
  - distance metrics
- to estimate the importance of threshold distances for connectivity

Study area & data

- southern Poland
  (the Polish Carpathians)



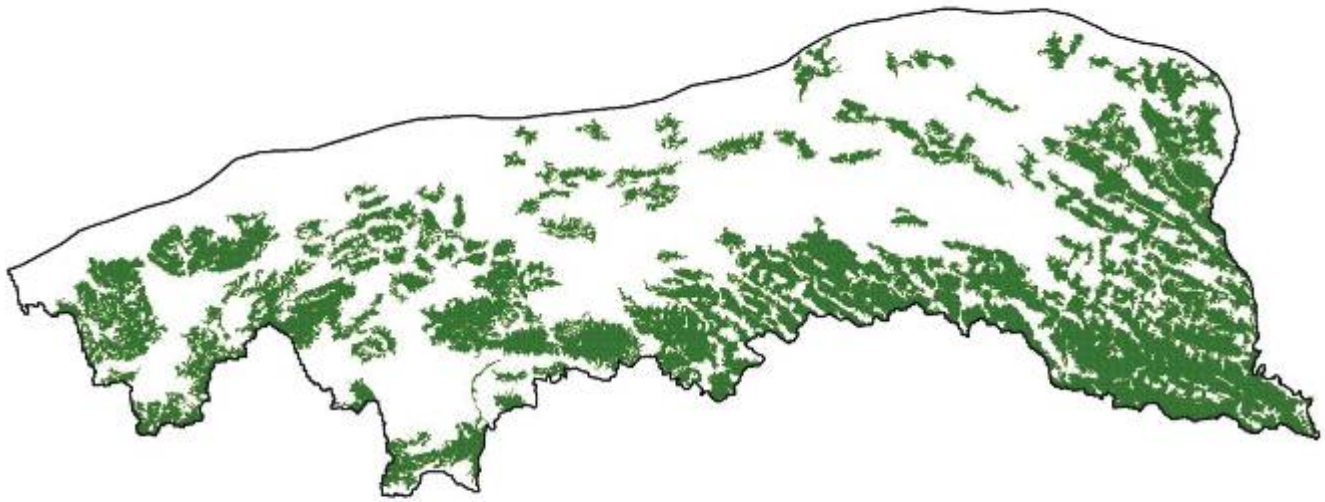
- data
  - CORINE land cover 2000
    - scale 1:100 000
    - 25 ha minimum mapping unit
    - raster data 100 m spatial resolution
  - SRTM database, version 4

Methods

1. identification of habitat patches
2. cost surface construction
3. nearest neighbour identification
4. patch-to-point transformation (nodes)
5. distance calculation (edge weight)
6. evaluation and comparison

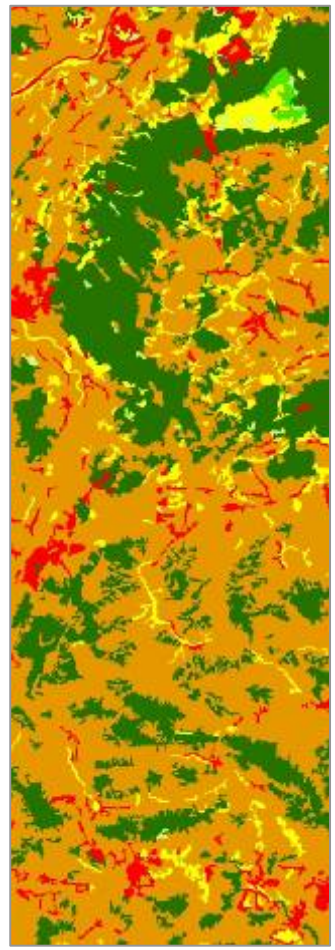
1. Identification of habitat patches

- contiguous forest areas larger than 10 km^2
  - broad-leaved, coniferous and mixed forests (CLC2000)



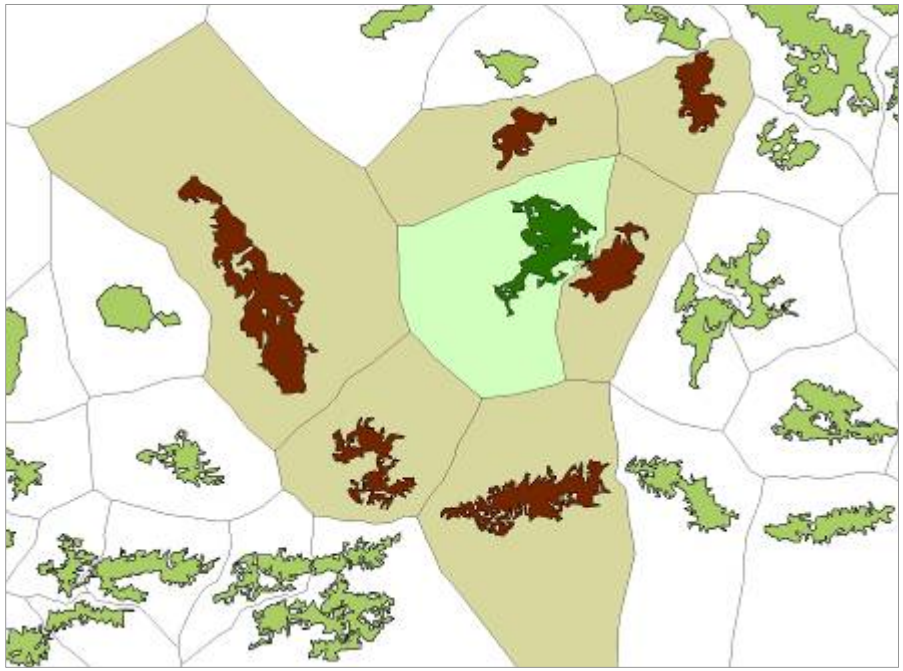
2. Construction of cost surface

- weights assigned to land cover classes
  - low: forested areas
  - high: artificial surfaces, water bodies
- weights assigned to slope gradients
  - low: flat or gentle areas
  - high: steep, rugged terrain
- summed into one cost surface



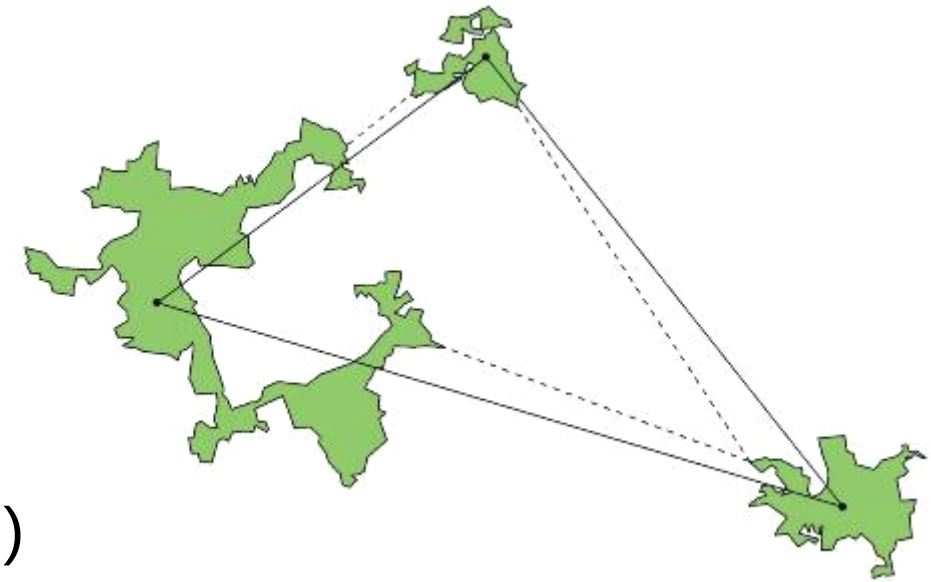
3. Nearest neighbours

- delimitation based on allocation methods
  - Euclidean allocation
  - cost allocation



4&5. Nodes and distances

- nodes
  - centroids (Model 1)
    - ‘centroid’ model
  - edge points (Model 2)
    - ‘patch’ model
- edges weights
  - Euclidean distance (EM)
  - cost distance (CM)

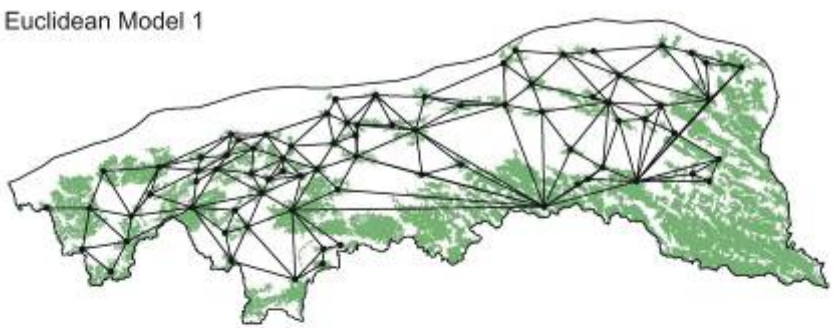


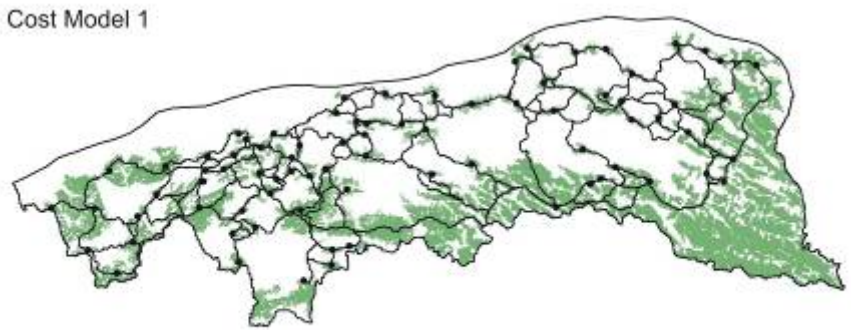
6. Evaluation and comparison

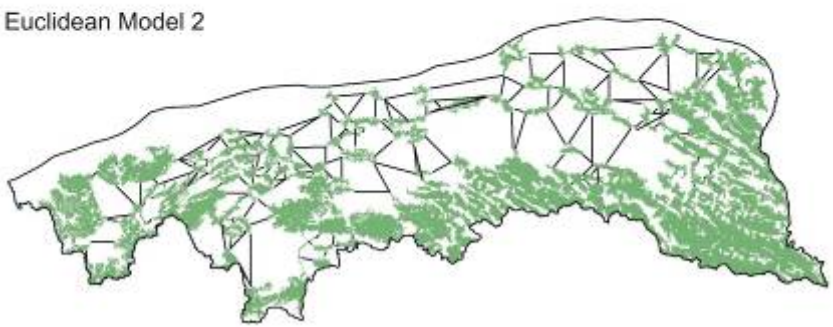
- standard graph indices
  - mean edge length
  - vertex eccentricity
  - radius and diameter
  - minimum spanning tree
- edge thresholding
- visual inspection

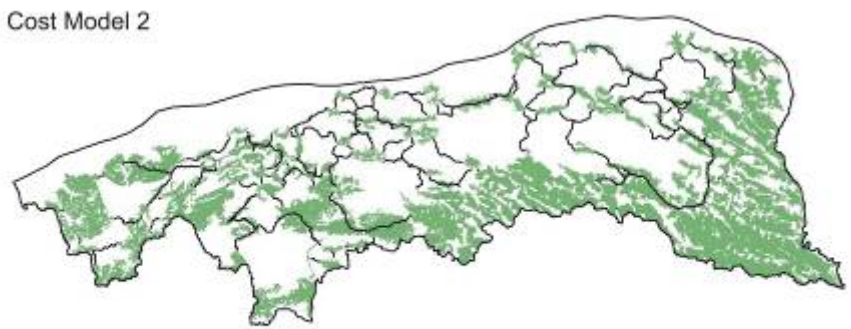
Results

- 4 models: Euclidean Model 1 (EM1), Euclidean Model 2 (EM2), Cost Model 1 (CM1), Cost Model 2 (CM2)



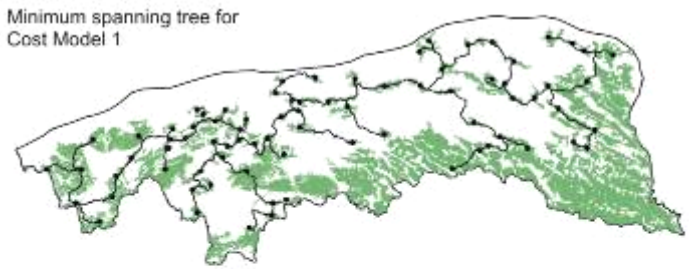


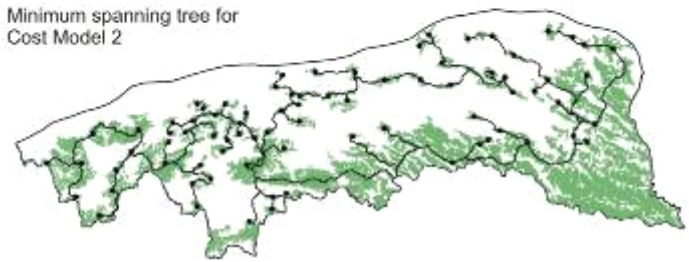




Standard graph indices

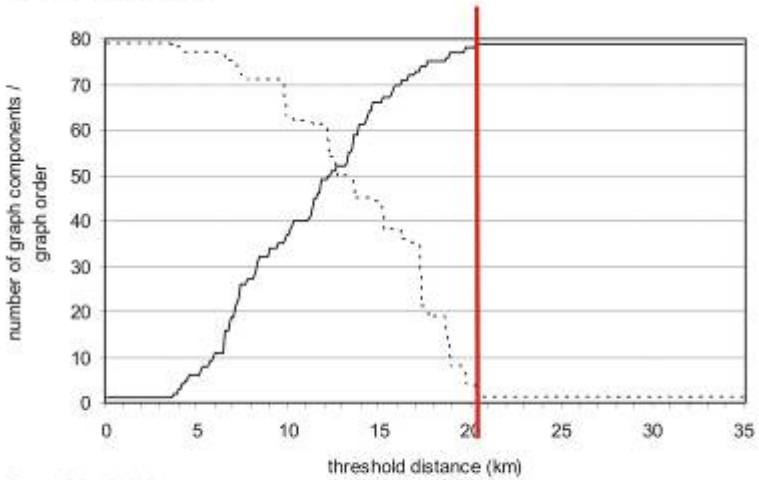
- values
  - cost models > Euclidean models
  - centroid models > patch models
- mean edge length
  - 5 km (EM2)
  - 28 km (CM1)
- mean node eccentricity
  - 20 km (EM2)
  - 286 km (CM1)
- minimum spanning tree
  - 109 km (EM2)
  - 1155 km (CM1)



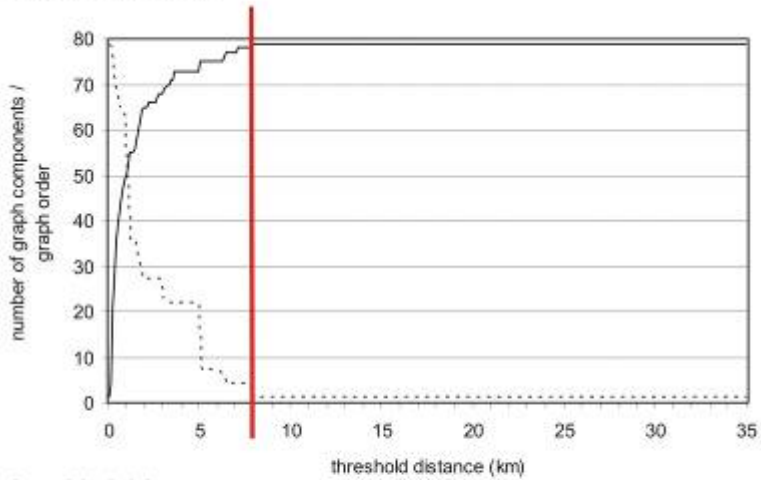


Edge thresholding

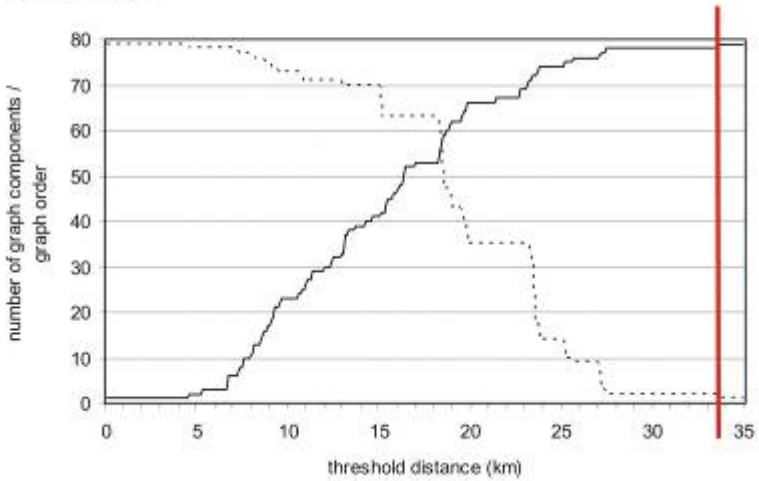
Euclidean Model 1



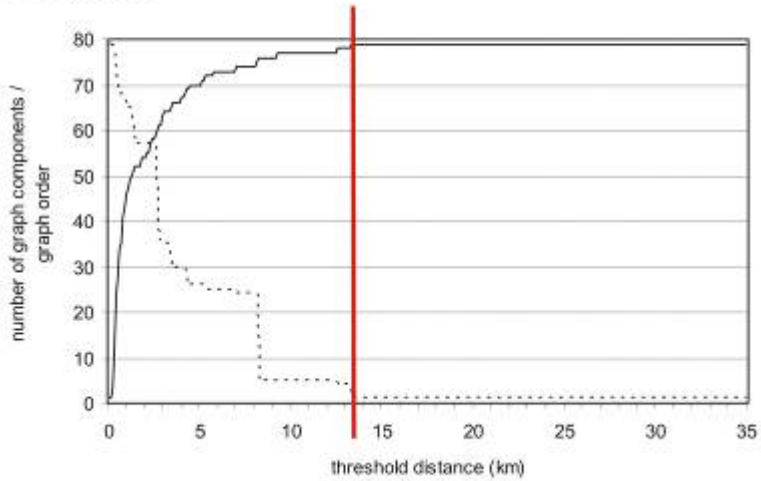
Euclidean Model 2



Cost Model 1

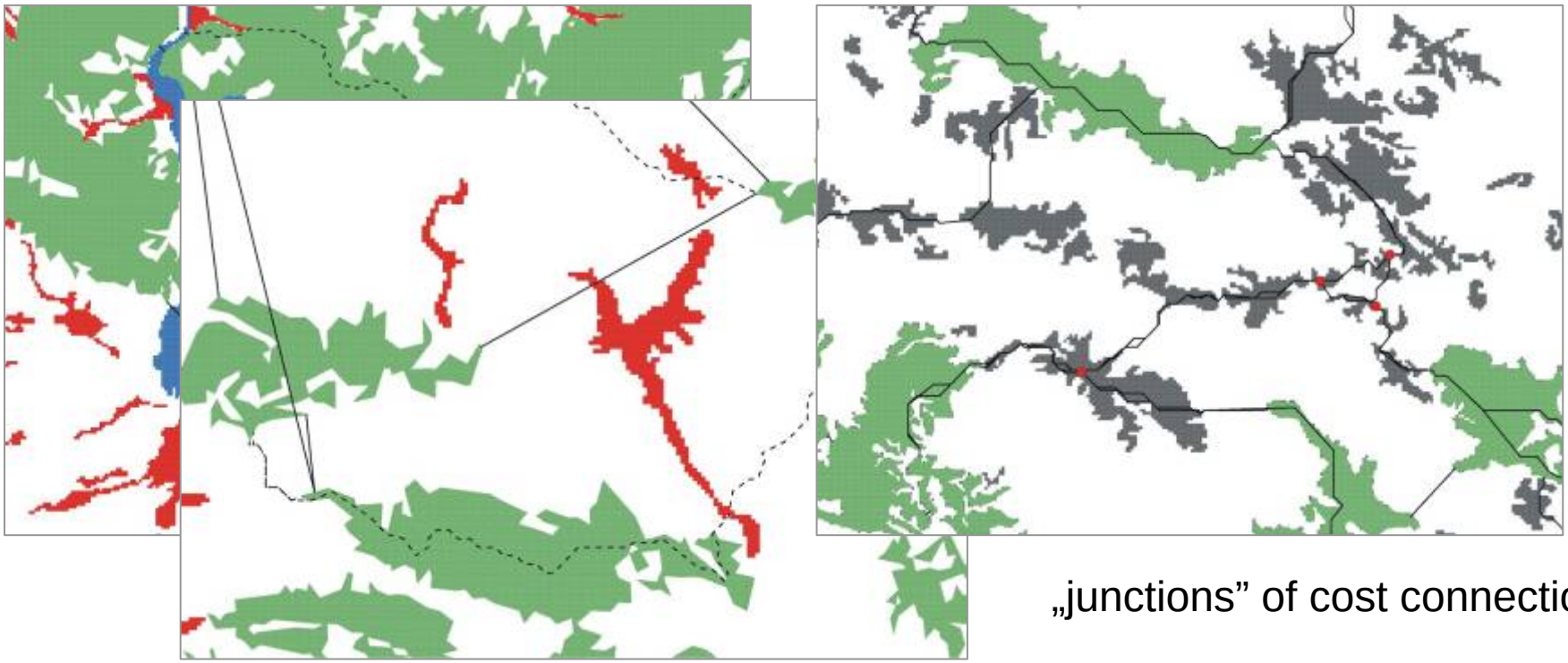


Cost Model 2



Visual inspection

Euclidean connections cross
artificial surfaces and water bodies



„junctions” of cost connections

cost connections cross additional,
neighbouring forest patches

Conclusions

- methods of graph construction have a decisive impact on results of landscape connectivity assessments
- differences between ‘centroid’ models and ‘patch’ models are larger than between ‘Euclidean’ and ‘cost’ models
  - polygon-to-point transformation more important than distance metrics
- cost models seem to better represent reality than Euclidean models
  - more useful to model functional connectivity ?
  - hypothesis to be tested against real-world data (species movement across landscapes)

Thank You!