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Identification of landscape corridors with the help of a new, graph-theory based, approach integrating functional connectivity and landscape configuration metrics

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Scope

The Problem

The Data

The Approach

The Tool

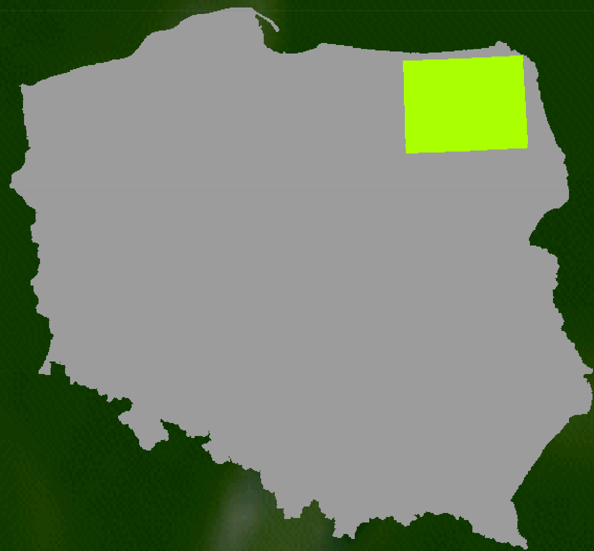
Results

Conclusion

The problem

Because of changes in land cover, and establishing new protected areas (Natura 2000 sites) there was a need to re-identify in a more detailed way ecological corridors linking nature protection sites in north-eastern Poland.

Area of approx. 15 000 sq. km.



The problem

Corridors for:

Roe deer (*Capreolus capreolus*)

Red deer (*Cervus elaphus*)

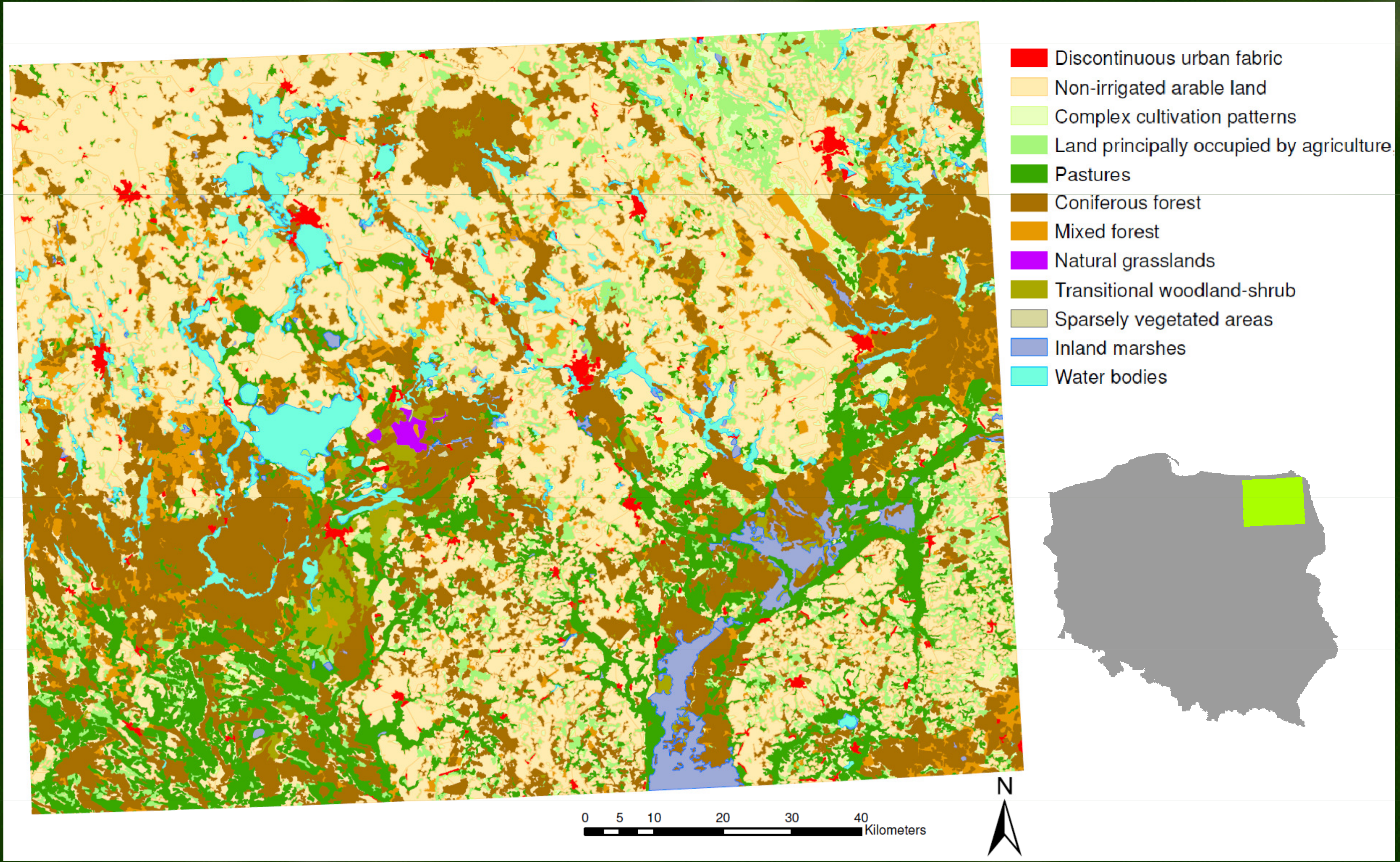
Each species has its own ecological niche but there is a common set of environmental preferences which might be used for modeling spatial distribution of ecological corridors

Moose *(Alces alces)*

Grey wolf *(Canis lupus)*

Data

Corine Land Cover 2006 vector map (the smallest patch > 25 ha)



The Approach

Background and Basic Assumptions

1. Working with vector data
   not raster data (cost-distance surface)

2. Animal mobility through a landscape depends on quality of
   patches and the border between patches

3. The corridors are identified along the minimum spanning
   tree derived from a weighted graph representing
   landscape mosaic

The Approach

Methods

Processing flow

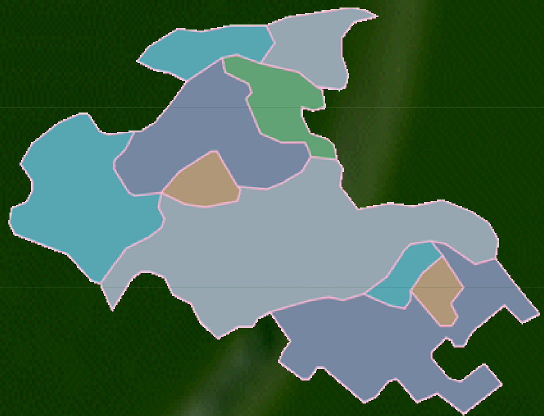
1. Vector Map → Unweighted Graph
2. Unweighted Graph + Mobility Model → Weighted Graph
3. Weighted Graph + Analysis Set → Reduced Weighted Graph
4. Minimum Spanning Tree (corridors) computation

Mobility Model – most important section in the procedure

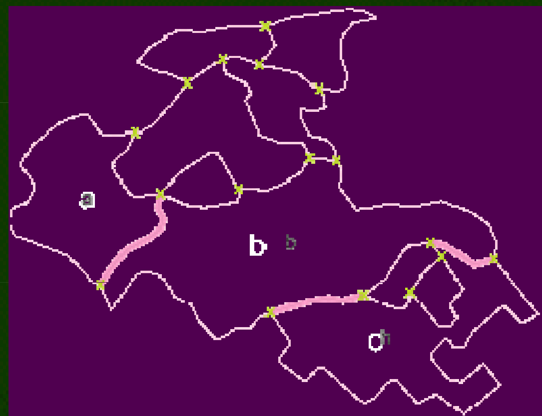
- normal model with Mobility Factors
- fallback model with steps

The Approach

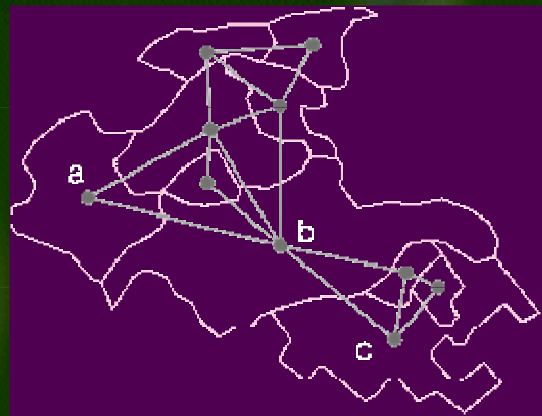
Processing flow – stage I – Topology building



patch map



shared borders → edges



unweighted graph

The Approach

Processing flow – stage II – Mobility Model

Mobility Factors

A. Patch resistance = resistance to travel – or alternatively – a cost of travel through a patch (graph node), specified as either or both:

A1. Patch Class Resistance (**PCR**), the user assigns resistance to whole classes of patches (like a land-use classification type),

A2. Patch Individual Resistance (**PIR**), the user assigns the resistance each patch individually.

Apart from assignment method both factors share the same interpretation and performance in calculations. First factor is better suited to capture high-level properties of mobile agent, second factor – to capture unique properties of patch which cannot be easily generalized, especially – geometry.

B. Transfer Resistance (**TR**) = resistance to (or inverse probability of) travel from patch to patch (node to node). This factor can only be assigned class-wide, like PCR, so actually it describes a relation between classes of patches.

The Approach

Methods - Mobility Model

Weight Formula

Three mobility factors are combined in order to get a single weight value for graph edge. For any adjacent *i* (origin) and *j* (destination) node pair, the formula is:

$$W(i,j) = \left(\frac{PCR(i) + PCR(j)}{2} + \frac{PIR(i) + PIR(j)}{2}\right) TR(i,j)$$

If one of mobility factors (PCR, PIR or TM) is not defined, then a value of 1.0 is assigned by definition.

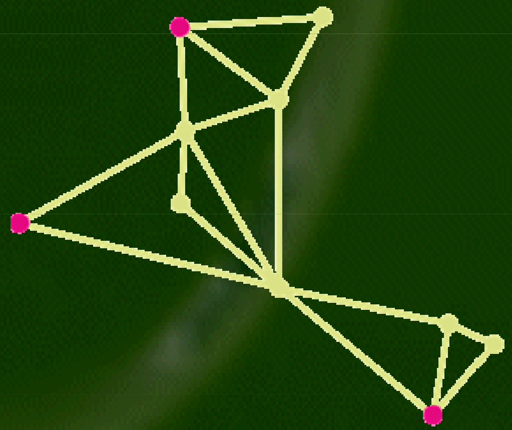
Weight Formula for step model

If **none** of mobility factors are defined, then the total weight of path equals to the number of "steps" made between path origin and destination, which is the same as the number of edges or number or crossed borders.

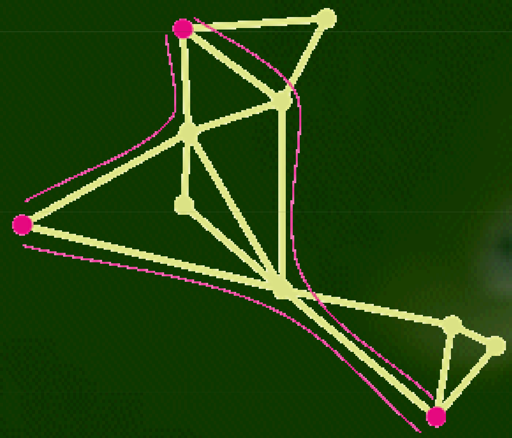
The Approach

Processing flow – stage III – graph reduction

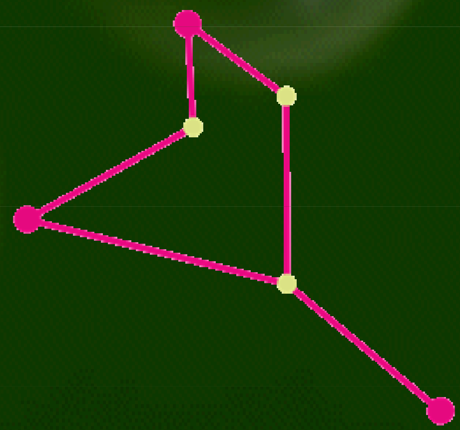
full graph



user selects Analysis Set nodes



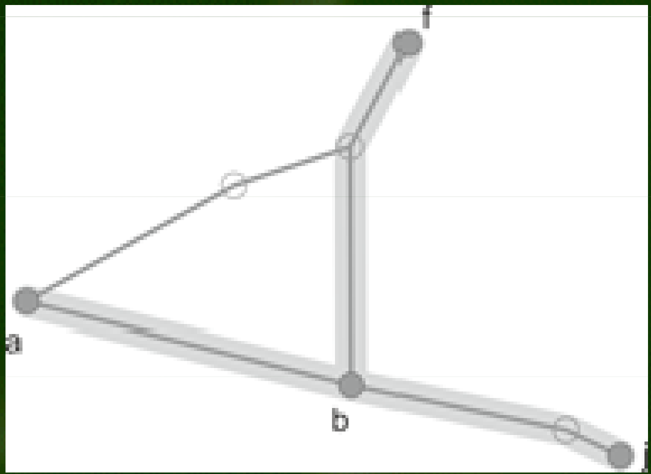
Dijkstra Shortest Paths Algorithm generates edges



reduced graph

The Approach

Processing flow – stage IV – Minimum Spanning Tree



MST is

- a tree (subgraph without cycles)
- connecting Analysis Set nodes
- with minimum summary weight (least cost)

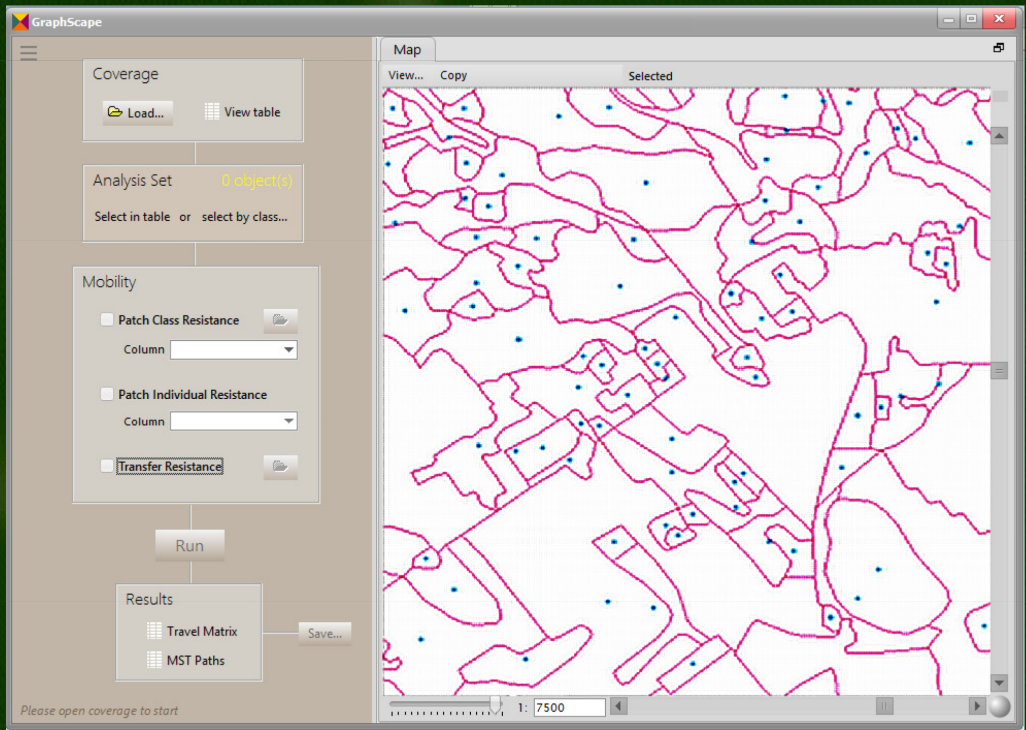
computed with Prim's algorithm

The Tool

available soon at: *www.igipz.pan.pl/graphscape*

GraphScape

new software, 64-bit, multiprocessing

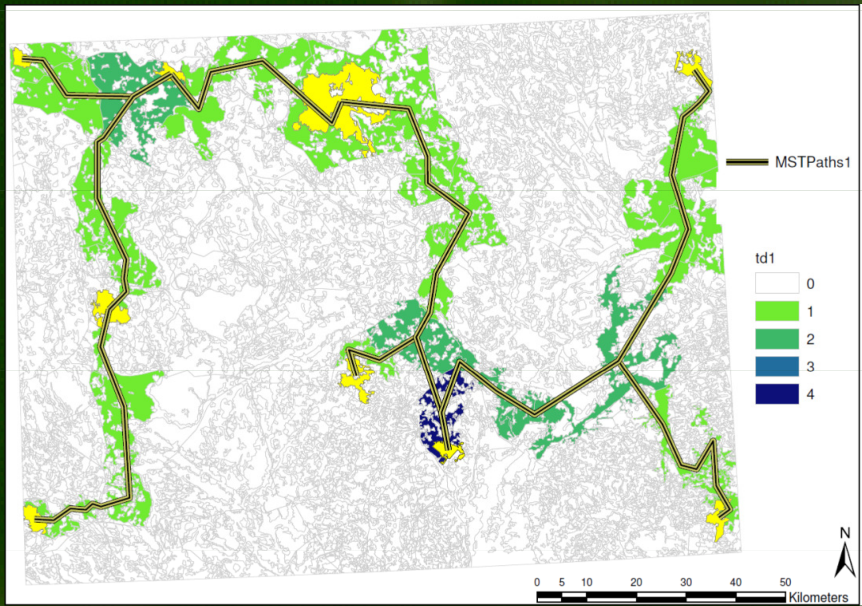


Outputs:

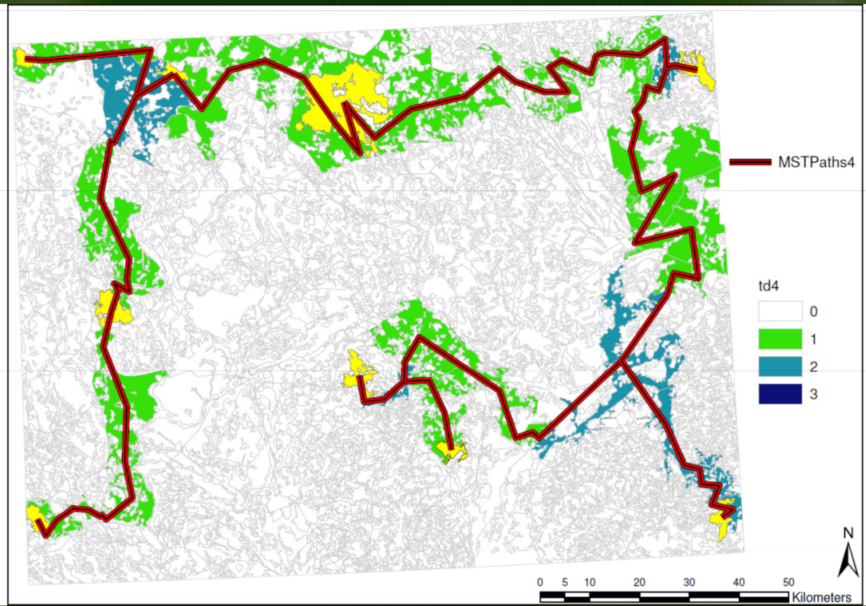
- MST skeleton lines (new shapefile)
- Transit Density (number of MST paths crossing a patch): a new column in a copy of input shapefile
- Shortest MST path (weighted distance to the same type patch): a new column in a copy of input shapefile
- Path statistics (a number of paths, summary weight, mean weight, st. deviation of weight, shortest path weight) – text report to copy-paste
- Full travel matrix – copy-paste

Results

Ecological corridors determined as Minimum Spanning Tree



no resistance (step model)



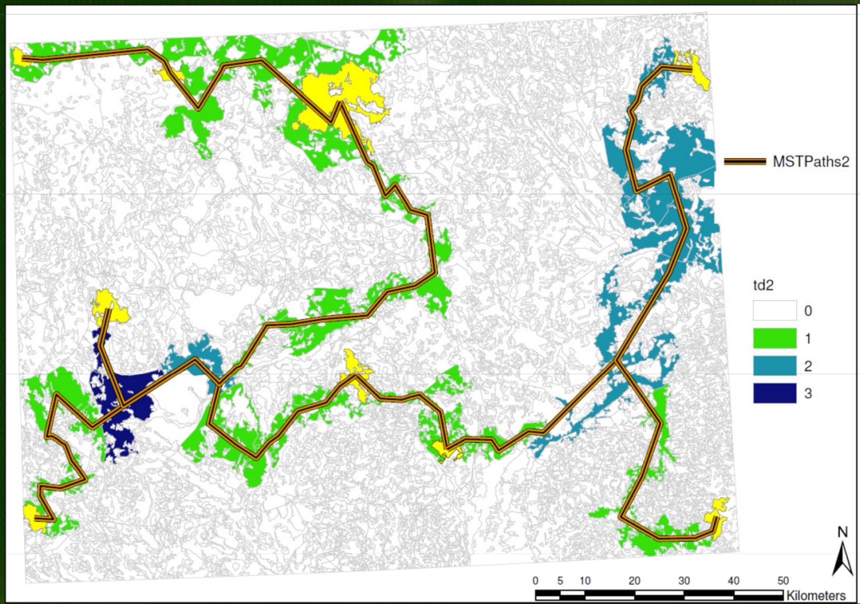
with transfer resistance

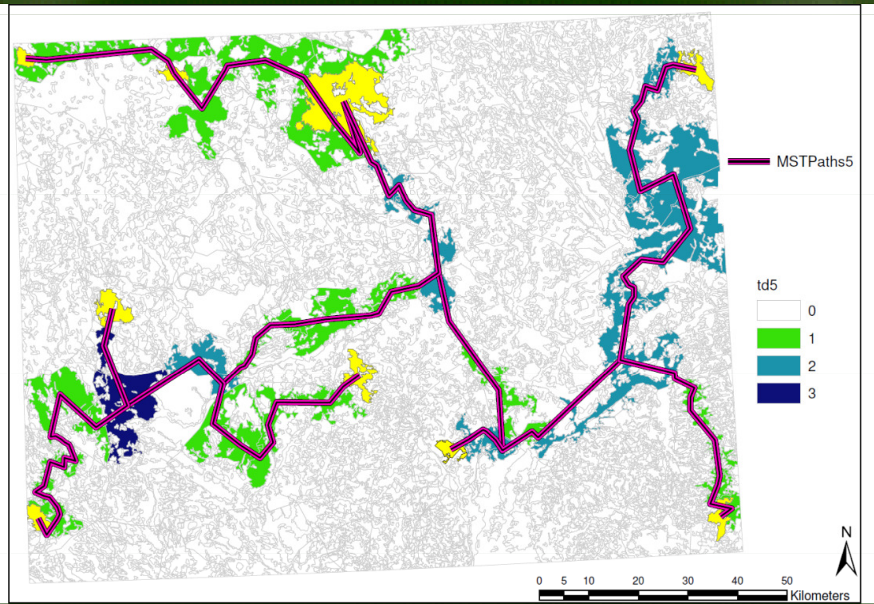
Number of Steps		Path weight	
mean	std. Dev.	mean	std. Dev.
8.13	3.10	8.13	3.10

Number of Steps		Path weight	
mean	std. Dev.	mean	std. Dev.
12.88	6.68	5.40	1.16

Results

Ecological corridors determined as Minimum Spanning Tree





with patch class resistance

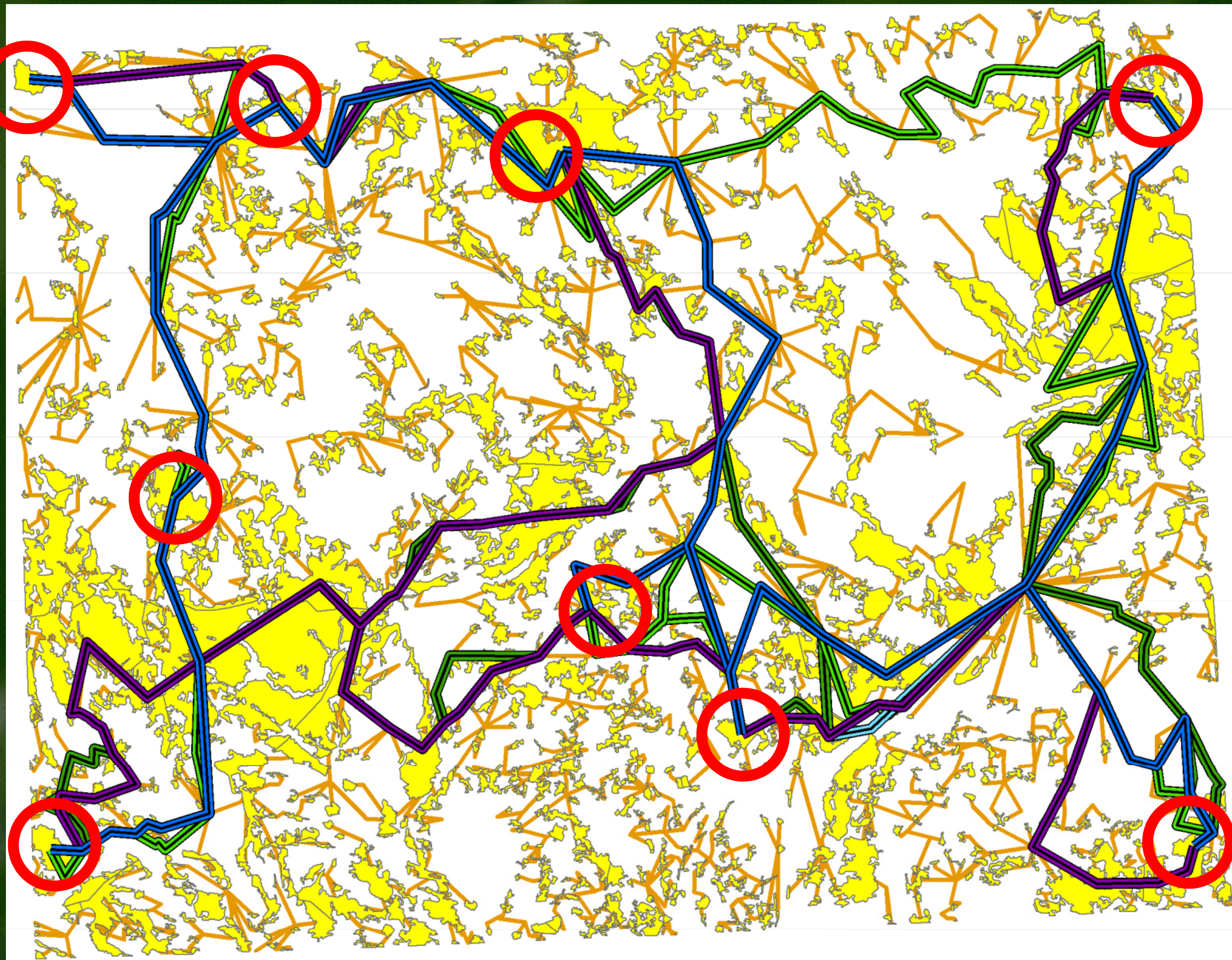
Number of Steps		Path weight	
mean	std. Dev.	mean	std. Dev.
13.13	6.25	2.45	0.61

with both patch class resistance and transfer resistance

Number of Steps		Path weight	
mean	std. Dev.	mean	std. Dev.
18.50	8.87	1.83	0.34

Results

The bunch of similar but not identical routes (results of the above modeling)



Yellow – all patches of pine and mixed pine forests
Brown – the shortest paths (the smallest number of steps) between patches of forests

Conclusion

1. New perspective in studying landscape connectivity:
   - new metrics describing ecological distances between patches (Patch metrics: transfer density index, number of steps;
   Path metrics: path length, path elongation index)
   - identification of the corridors on the basis of the minimum spanning tree in the graph

2. The bunch of similar but not identical routes (results of the modeling with changing parameters) together better represent functional connectivity between patches

3. The identified routes (corridors) could be the basis for spatial planning for nature protection and landscape structure optimization (having in mind that animals movement across landscape depends also on the total permeability – which could not be protected forever)

modelling for protection ≠ modelling for truth

Thank You for attention

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