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METHOD DESCRIPTION

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Connectivity mapping - protocol

The following describes in detail the procedure employed to calculate and map connectivity of old spruce and pine forest in Dalarna county, using the connectivity metric of (Mair et al., 2017).

Required indata

- KNN raster files for **forest age** and **volume of target tree species** (spruce, pine, etc.); KNN skogskarta 2010 data has resolution 25m, coordinate system RT90 (EPSG:3021)
- Shapefile outline of county (here: Dalarna), projected to same CRS (RT90). This can for example be downloaded at gadm.org
- Optional additional input data: maps of forest continuity for the boreal region, available from Metria via Miljödataportalen.

Procedure

Create input raster files

To reduce the file size of input rasters, clip them to a smaller extent using GIS software of your choice. The extent should include the county outline as well as a buffer zone around the county to include forest beyond the county borders into connectivity estimates.
Here, all rasters are clipped to the county outline plus a 20km buffer area beyond the county. This threshold is used because probabilities of dispersal from >20km around a focal site are very low when assuming a negative exponential kernel with a mean dispersal distance of 1 km (at distance of 20km, the probability of dispersal into the focal cell is p = 2.06e-09). If a different kernel is used or if mean dispersal distance is assumed to be greater than 1km, other threshold values should be used (see Table 1).

In QGis, the following steps can be used to achieve this:

- Load required files (CRS RT90)
- Create buffer outline using county border shapefile and tool Vector > Geoprocessing tools > Fixed distance buffer
- Clip rasters using tool Raster > Extraction > Clipper (set nodata value to zero; tick “crop the extent of the target dataset to the extent of the cutline” to reduce raster size)

Calculate connectivity

Implemented in R script ConnectivityMapping.R

Main steps are:

- Read in raster files and set coordinate system
- Based on forest age raster, select cells in the target tree volume raster (e.g. spruce volume) that are at least 100 years old (set no data value to zero to facilitate later calculations)
- Aggregate (average) to lower resolution (100m pixel size) for faster calculation
- Construct a moving window matrix with weights based on distance and the dispersal kernel of choice
- Calculate connectivity using function `focal()`
- Crop and mask output raster by county borders (to remove buffer zone)
- Save output rasters

Note, in comparison to the kernel density tool of ArcGIS (värdekärnor delineation), the shape of the distance decay weight function can here be adjusted to a biologically informed dispersal kernel that captures the probability of arriving from a certain distance. Similar to the kernel density tool however, for computational feasibility, also here a threshold distance is set over which the calculation is made. In practice, the threshold distance is chosen such that the probabilities beyond are so small that the connectivity value will not be affected noticeably.

This means that the buffer radius and threshold distance must be adjusted for the mean dispersal distance chosen. For larger mean dispersal distances, the threshold radius should be set such that the results are not affected; the buffer area around the county borders, which is included in the calculation to remove edge effects, should then also be extended. If we assume that a threshold probability of 1e-06 will not affect results noticeably, we can calculate minimum threshold radii for different dispersal kernels. In the case of a negative exponential kernel, the minimum threshold distance D for a probability of dispersal of P ≤ 1e-06 is $= -\ln(P)/\alpha$.

Smaller threshold distances might lead to underestimation of connectivity by disregarding farther away but potentially valuable habitat that is still within reach of dispersing individuals.

Table 1. Minimum threshold radii for different values of mean dispersal distance 1/α for the negative exponential kernel.

Dispersal kernel	**Formulation**	**Mean dispersal distance**	**Mean dispersal distance (km)**	**Minimum radius for calculations**
Negative exponential	P = exp(-α *distance)	= 1 / α	0.2	2.76
			1	13.82
			5	69.1

In practice, changing the threshold radius requires adjusting: i) the buffer area around the county borders, and ii) the size of the moving window used by function `focal()` in the connectivity calculation. This is set as `myradius` (in meters) in the beginning of the script. Input rasters should be adjusted beforehand.