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Short Paper

Noah Greupner

Lynx Habitat Change Assessment Using Landscape Metrics

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Abstract

The Eurasian Lynx (*Lynx lynx*) is a European predator cat which is currently reintroduced in many European regions. The county of Cham in South-East Bavaria is considered a propagation corridor for the species, potentially connecting the Bohemian-Bavarian-Austrian Lynx Population with possible habitats further north. This short paper uses landscape metrics to assess the habitat changes experienced by the lynx in Cham between 2000 and 2018 and evaluates the results by linking them to the species' requirements. Specifically, six different metrics are used to measure habitat changes between the two years. These metrics are (1) Mean Patch Size, (2) Total Class Area, (3) Proportional Class Area (4) Patch Density, (5) Largest Patch Index and (6) Euclidean Nearest Neighbor Distance. By doing so, this paper contributes to understanding the impact of habitat changes on lynx populations and, thus, helps to develop effective conservation and propagation strategies in the region.

Introduction

The lynx requires large connected and compact forested areas for living. Extensive hunting and habitat fragmentation almost caused the extinction of the lynx in many European regions in recent centuries (Port et al., 2021). In Bavaria, lynx conservation efforts like the international *3Lynx* project have recently focused on reintroduction. However, the population has been stagnant for several decades since the late 1990s (Magg et al., 2016). This threatens the reintroduction effort's success as small, isolated populations have smaller genetic variability, leading to less reproductivity and even resulting in population extinction (Magg et al., 2016). During the migration phase of the lynx, direction and migration routes are linked to the presence and distribution of forests and forest corridors (Schadt et al., 2019). Therefore, the availability of sufficiently large and connected habitats is crucial for the propagation and growth of the Bohemian-Bavarian-Austrian population.

When Schad et al. developed a habitat suitability model in the year 2000, the county of Cham in Eastern Bavaria was considered a potential propagation corridor for the species. However, lynx occurrence data from the years 2012-2016 reveal that there is no permanent lynx occurrence beyond the borders of the county (see Figure 1). There is, therefore, need for further research on this topic to assess potential habitat changes.

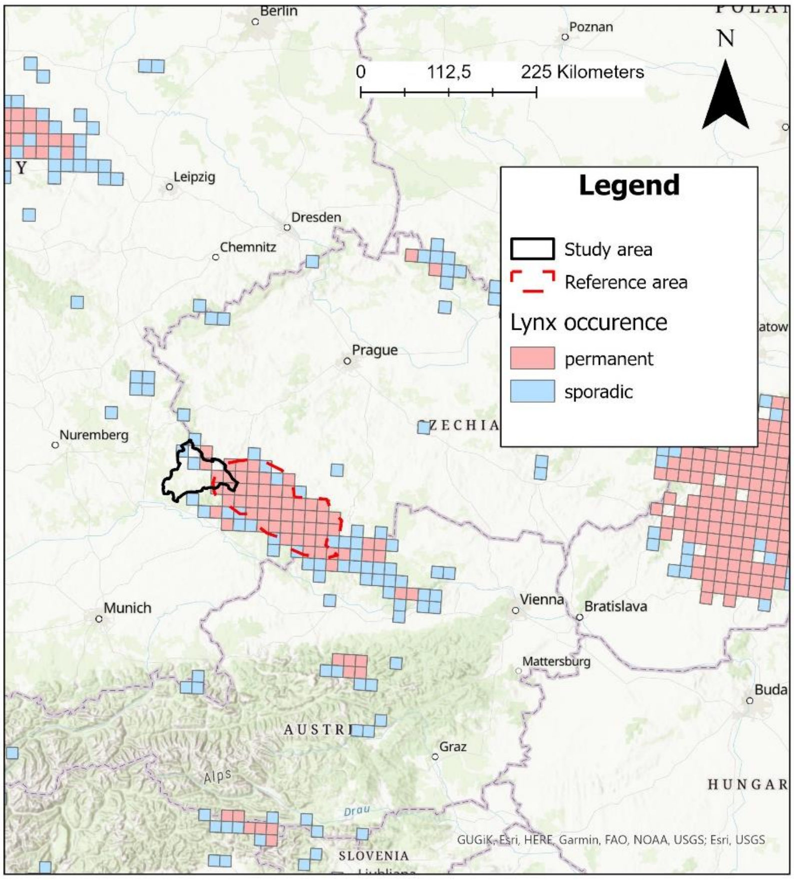

Figure 1: Study and reference area together with lynx occurrence data (Source: see "methods").

When it comes to landscape and habitat change analysis, landscape metrics have proven to be valuable for assessing habitat alterations and their potential consequences for wildlife (Frazier and Kedron, 2017), as they are based on the assumption that there is a reciprocal relationship between spatial patterns and ecological processes. They are quantitative measures used to provide a characterization of the structure, composition, and spatial patterns of landscapes (Gustafson, 2019; Hesselbarth et al., 2021) and are utilized to describe the spatial organization of land cover classes and other landscape features such as patches, corridors, and edges. Metrics can be calculated on different spatial levels. Patch-level metrics describe patches as adjacent cells belonging to the identical land cover class. Class-level metrics represent all patches of a specific class and landscape-level metrics specify the whole landscape (Hesselbarth et al., 2019). After the initial developments of landscape metrics in the 1980s, software such as FRAGSTATS were developed in the 1990s, specifically for facilitating the automated calculation of landscape metrics. During this time, the methodology of landscape metrics experienced great popularity and has since then made enormous progress in the understanding of the basic characteristics of spatial patterns, in the methods for quantification and in technical developments (e.g. advancement of remote sensing) (Gustafson, 2019).

By applying landscape metrics on relevant land use/land cover data for the years 2000 and 2018 and combining them with specific literature, this short paper seeks to elucidate the extent and spatiotemporal patterns of forest changes in Cham and their potential effects on lynx habitat suitability and propagation potential.

Methods

The methodologic workflow of this study can be seen in Figure 2. In the following sub-chapters, the most important workflow steps are described in detail.

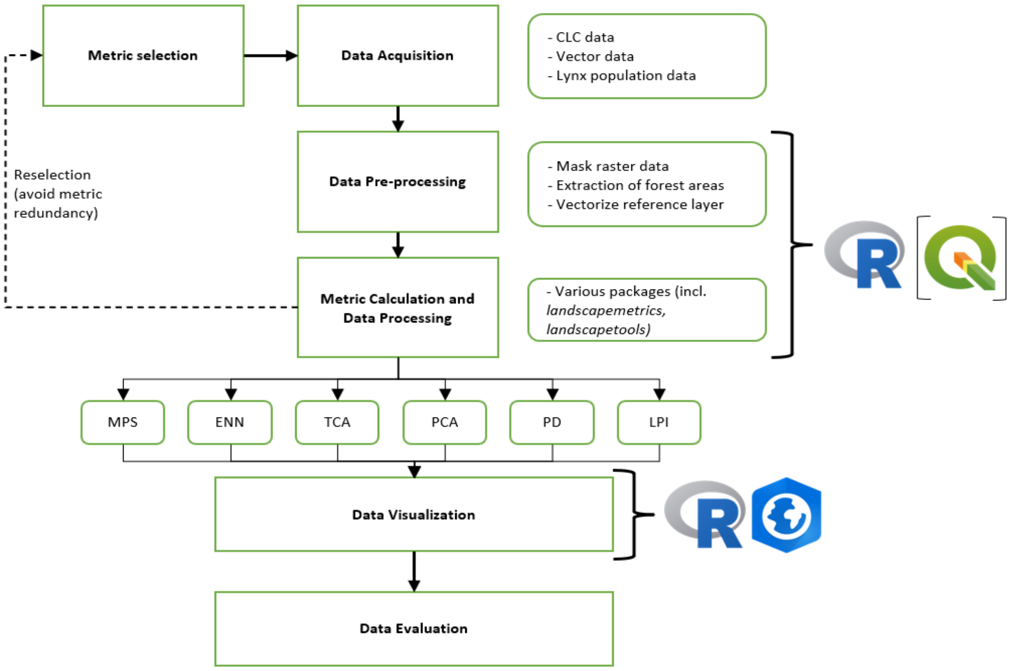

Figure 2: Workflow diagram of the conducted research (own representation).

Metric selection

Metrics were selected based on literature, habitat requirements, and correlation test. Studies that were used to guide the selection of metrics include Da Silva et al. (2021), Yang (2021), and Mehta et al. (2022) all of which analyzed spatiotemporal forest changes with landscape metrics. In addition, metrics were selected according to the habitat requirements of the lynx. The species needs large, unfragmented and connected forests, far away from human influence (Port et al., 2021). For this reason, Mean Patch Size (MPS) and Patch Density (PD) were chosen, which are indicators of landscape fragmentation (Hesselbarth et al., 2019). They are simple ways of describing the forest composition. In addition, an important measure of the size of potential habitat is the Largest Patch Index, which gives the percentage of the landscape covered by the largest forest patch. The central metric for connectivity of the area and thus for the function of the study area as a dispersal corridor is the Euclidean Nearest Neighbor Distance (ENN). This metric measures the distance to the nearest patch in either four or eight directions (Hesselbarth et al., 2019). Table 1 shows more detailed information about the selected metrics.

According to Gustafson (2019), it is advisable to conduct a correlation test on the metrics to exclude redundant ones. Thus, a correlation test was applied to the reference area (see Figure 3). ENN as the central metric does not correlate with other metrics, therefore only the Total Core Area had to be removed from the initial selection phase. It must be said that the ENN has been calculated both at the class and the patch level. This was done to analyze a more accurate picture of the distribution of values between the two years, which would not be possible with one mean value from the class level.

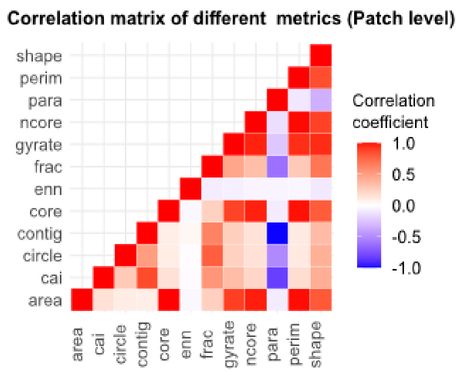

Figure 3: Correlation matrix of possible metrics, calculated on patch level (own representation).

Table 1: Final selection of the landscape metrics.

Name	Level	Type	Description	Unit
Mean Patch Size	Class	Area & edge metric	Average size of forest patches in the landscape	Hectares
Euclidean Nearest Neighbor Distance	Patch, Class	Aggregation metric	Average distance between forest patches in the landscape	Meters
Total (Class) Area	Class	Area & edge metric	Total forest area	Hectares
Proportional (Class) Area	Class	Area & edge metric	Percentage of forest in the landscape	Percentage
Patch Density	Class	Aggregation metric	Number of forest patches per unit area of the landscape	Number per 100 hectares
Largest Patch Index	Class	Area & edge metric	Area of the largest forest patch in the landscape	Percentage

Data acquisition

When applying landscape metrics, land use/land cover data is required. This data was obtained for the years 2000 and 2018 from the CORINE Land Cover inventory which is coordinated by the European Environment Agency (EEA) and provides standardized land cover and land use data for the entire European continent in 44 land cover classes. The dataset is updated every six years and can be downloaded either as a vector or as a raster dataset. Since R was used for calculating the metrics in a subsequent step, raster data was obtained.

Vector data of the study area was requested as Web Feature Service from the German Federal Agency for Cartography and Geodesy and lynx occurrence data was received from the Large Carnivore Initiative for Europe. This is an expert group coordinating periodic surveys and collecting occurrence data from large carnivores in Europe (Kaczensky et al., 2021). The data is provided in an aggregated manner in 5x5km rectangles and was processed in QGIS to derive a reference area where lynx occur permanently. For doing this, a polygon was drawn around a core zone with permanent lynx occurrences (see Figure 1). This was done to compare the reference area with the results from the study area which allows for a better assessment of the results about the suitability of the habitats. A reference area close to Cham was chosen to ensure comparability in terms of population, diet, habitat requirements and climatic conditions.

Data pre-processing

The data pre-processing phase encompassed several steps. First, a shapefile for the reference area was created. Secondly, R was used to mask the CLC data to the boundaries of Cham and the reference area. For the reference area, only the CLC data from 2018 was used since only one value is required as a reference. Subsequently, the classes 311-313 of the CLC data, which represent forested areas (311: coniferous forest; 312: broad-leaved forest; 313: mixed forest), were extracted from the data and merged in R. Therefore, it was continued with a binary classification of two classes (forest; no forest). All other classes could be neglected for the metric calculation since lynx habitats solely consist of forested areas (Port et al., 2021).

Metric calculation

The *landscapemetrics* package in R was primarily used to calculate the six metrics. The l*andscapemetrics* tool was developed by Hesselbarth et al. (2019) and contains a large number of commonly used metrics. Unlike other software, it is open-source and can be easily integrated into large workflows (Hesselbarth et al., 2019). In parallel to calculating the six metrics, the package was also used to visualize the ENN for the two years, as it is a key metric. Additionally, the ENN values calculated on the patch level were visualized using boxplots.

Data evaluation

For evaluating the obtained metric values for the study area in 2000 and 2018, the values from the generated reference area was used to compare the actual landscape composition and configuration of the study area with permanent habitat data to ensure drawing well-founded conclusions about the suitability of Cham as a habitat and as a dispersal corridor for the species. In addition to this, the following habitat requirements from Schadt et al. (2000) were consulted in this study as a component of evaluation: (1) open areas of over 1km length act as a barrier; (2) the minimum size of forested areas where a lynx resides permanently is 30km^2. However, these reference values originally come from habitat requirements in the Swiss Alps and, therefore, do facilitate only limited comparability.

Results

Visually interpreting the forest cover in Cham between 2000 and 2018, there are no major changes (see Figure 4). However, small alterations can be detected, especially in the West of the county, where small, fragmented forest patches are still dominating.

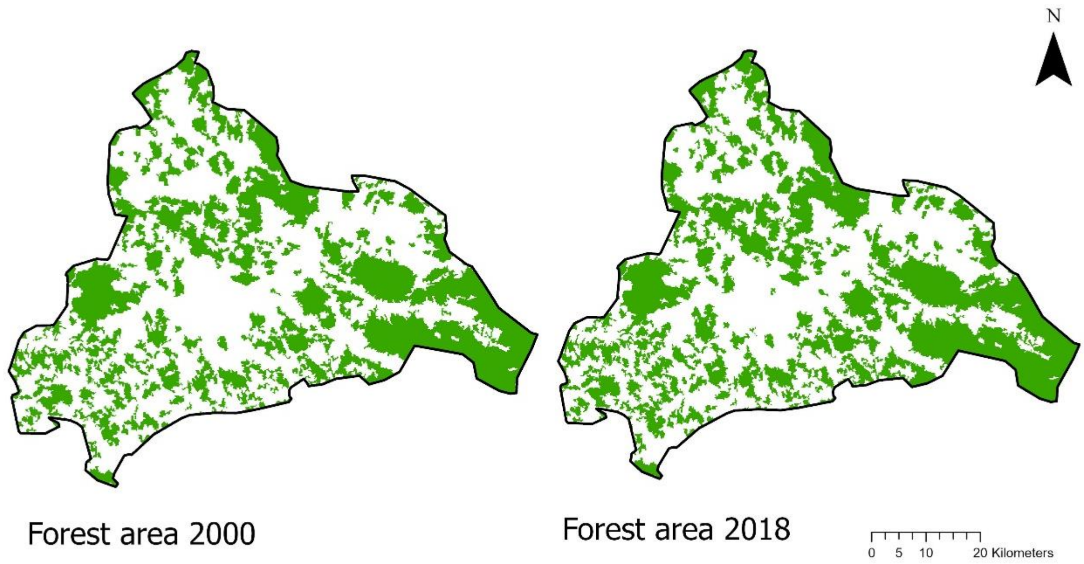

Figure 4: Comparison of the forested areas in Cham in the years 2000 and 2018 (own representation).

By looking at the statistical results of the calculated landscape metrics (see Table 2), we can see that the Mean Patch Size slightly increased from 338 ha to 344 ha, while the total forest area increased by around 500 ha and the proportional forest area is 41,3% while it was 40,9% in the year 2000. The Euclidean Nearest Neighbor Distance slightly decreased from 331 m to 325 m. The density of the forest patches slightly decreased and also the largest forest patch has reduced in size by around 0,2%. However, the Mean Patch Size of the reference area is more than double the size of the study area, while the Proportional Class Area is around 55%. The largest patch fills around 44% of the whole landscape. In addition, the Euclidean Nearest Neighbor Distance is around 288 meters which is shorter than those values from the study area.

Table 2: Results of the landscape metrics calculation.

Name	2000	2018	Reference	Unit
Mean Patch Size	338,37	344,87	796,42	Hectares
(Mean) Euclidean Nearest Neighbor Distance	331,04	325,36	288,38	Meters
Total (Class) Area	61.584,00	62.076,00	266.803,00*	Hectares
Proportional (Class) Area	40,981	41,309	55,584	Percentage
Patch Density	0,1211	0,1197	0,0697	Number/100 hectares
Largest Patch Index	11,1625	10,9429	43,8748	Percentage

* limited comparability due to differing size of the landscape.

When visually plotting the Euclidean Nearest Neighbor Distance metrics for both years (see Figure 5), it can be seen that most of the patches are located up to 800 meters from the nearest patch. The minority of the patches are located further than 800 meters from the next forest patch. Very few observations are isolated by more than 1200 meters.

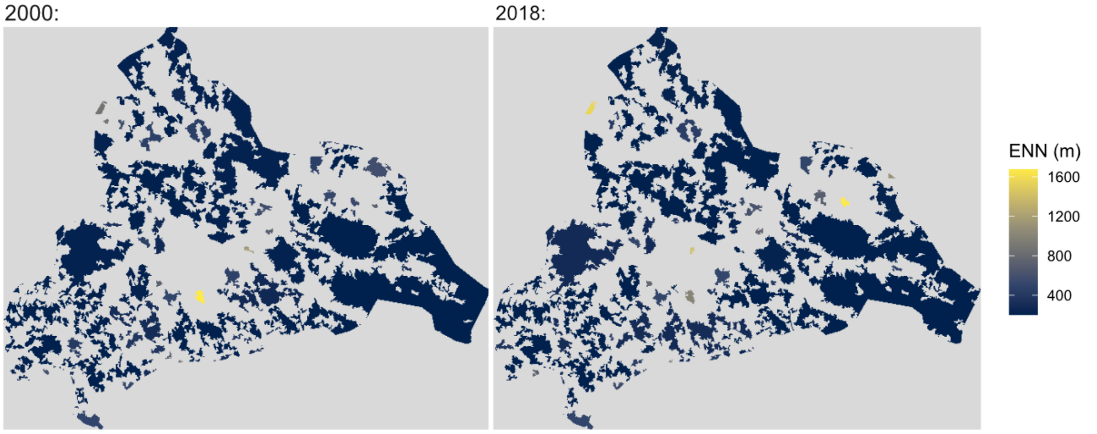

Figure 5: Comparison of the Euclidean Nearest Neighbor Distances between forest patches of Cham for the years 2000 and 2018 (own representation).

Figure 6 shows the distribution of Euclidean Nearest Neighbor Distance values between 2000 and 2018 (below 1000 meters). It can be seen that fewer outliers are located in the upper range between 800 and 1000 meters and that the upper quartile is lower.

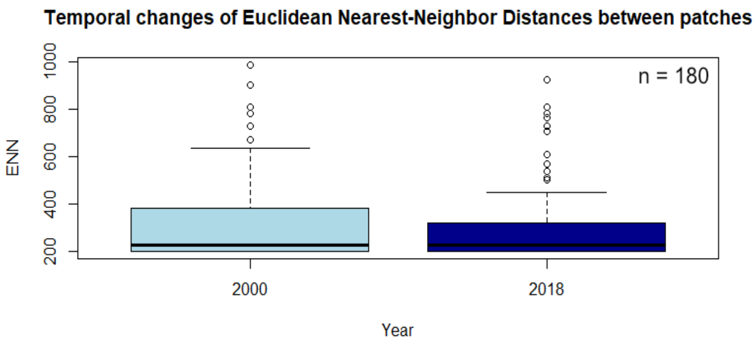

Figure 6: Boxplots of the Euclidean Nearest Neighbor Distance values of the individual patches (own representation).

Discussion

When comparing the metric values of the year 2000 with those from 2018, a slight overall improvement in the county's forests concerning lynx habitat requirements can be detected. Both the average size of forest patches and the total forest area increased. Furthermore, the distance between the patches decreased in general, leading to better habitat connectivity. However, in general, the forest composition and configuration of the study area are considered to be less favourable for the lynx than in the selected reference area, where lynx are permanently resident. In particular, the proportion of forest area to total landscape as well as the mean size of individual forest patches and the extent of the largest contiguous forest area are significantly more lynx-friendly in the reference area than in Cham. Although Cham's largest patch in 2018 covers about 68km^2, and is therefore suitable for lynx in principle, this is still far below the area of the largest patch of the reference area.

The results also show that forest connectivity itself is not the limiting factor and it is, thus, still theoretically possible for the species to use the forests of Cham as stepping-stone biotopes to migrate to potential habitats to the north. The findings, thereby, support the lynx distribution of the occurrence data (see Figure 1). That this migration has not yet transitioned into permanent residency may be due to illegal kills, which according to Megg et al. (2016) may have also hindered the establishment of a permanent population in these areas.

However, the findings described above are influenced by limitations affecting the expressive power of this study. According to Schadt et al. (2000), human infrastructure such as settlements and highways, as well as rivers act as barriers for the species and represent habitat boundaries. These factors were not included in the habitat analysis. Moreover, edge effects are influencing the meaningfulness of the results since forest patches which also extend beyond Cham were cut by the study area’s boundaries.

Conclusion

This short paper aimed to investigate the lynx habitat changes in Cham between 2000 and 2018 with landscape metrics. Based on the results, it can be said that it is not the connectivity of the forest patches so much as the small size and thus the undisturbed nature of the forests that has so far prevented the lynx from settling permanently in the entire area of the county and beyond. Moreover, other studies also show that in addition to habitat availability, factors such as the illegal killing of individuals outside of protected national parks have an impact on population stagnation in the area. The results of this study can contribute to a better understanding of lynx habitat requirements and, thereby, lead to improved lynx habitat management in Cham.

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