An Investigation into Urban Ecosystem Restoration to Address the Issues Presented in the Climate-Biodiversity-Society Nexus

H.R.A. Pownall, P.J.A. Burt, T. Santi**ka**

University of Greenwich

INTRODUCTION

It is generally well known that climate change, biodiversity and human health and wellbeing are intricately related. This idea has been explored more recently by Portner, *et al.* (2021), and Korn *et al.* (2019), and the main ideas are summarised in Figure 1. In the midst of the United Nation's 'Decade on Ecosystem Restoration' (2021-2030), a lot of work is being done to restore degraded ecosystems and reintroduce vital biodiversity and ecosystem services globally. However, little has been done to implement ecosystem restoration in the urban environment, where climate change, biodiversity and human health and well-being issues are often exacerbated and inter-related. A novel project, known as 'Stadte Wagen Wildnis', has attempted to address this and reintroduce healthy, diverse ecosystems to three German cities. This paper makes use of spatial analysis and biodiversity distribution modelling to assess the change in ecosystem status before and after the initiation of 'Stadte Wagen Wildnis'.

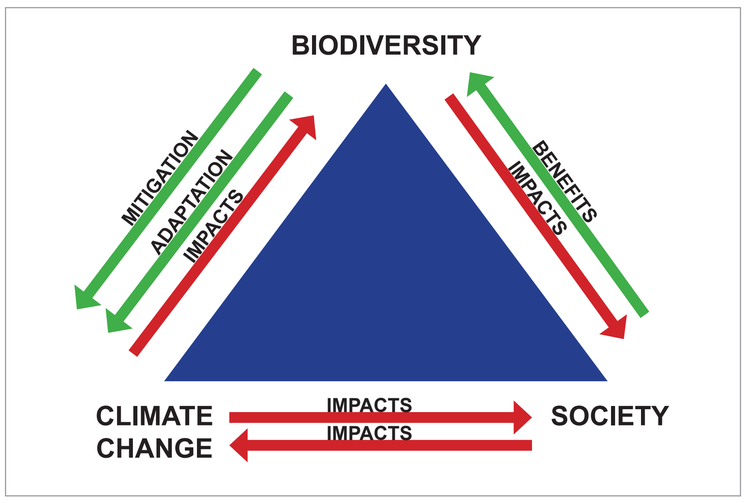


Figure 1: Diagram illustrating the Climate-Biodiversity-Society nexus, adapted from Portner et al. (2021).

AIM: Can urban ecosystem restoration address the issues presented in the Climate-Biodiversity-Society nexus?

OBJECTIVES:

1. Make use of spatial analysis and biodiversity distribution modelling to study an existing urban restoration project
2. Make use of ecological indicators to assess the health of an urban ecosystem before and after restoration activity took place
3. Draw conclusions about the state of biodiversity and associated ecosystem services.

METHOD

1. Site Selection

'Stadte Wagen Wildnis' (SWW) was chosen as an example of urban ecosystem restoration to be analysed. SWW took place from 2016 to 2021 in the German cities of Frankfurt, Hannover and Dessau-Roßlau. Each city adopted a different restoration methodology that was suited for the specific demography and project areas. Due to time and resource constraints, only Hannover's restoration sites were assessed. Hannover was selected as the preferred city for analysis as it maintains a fairly stable population, characteristic of many European cities in the 21st Century (WBD, 2022) and because the sites chosen for restoration varied greatly in their composition and were integrated seemlessly into the cityscape as seen in Figure 2.

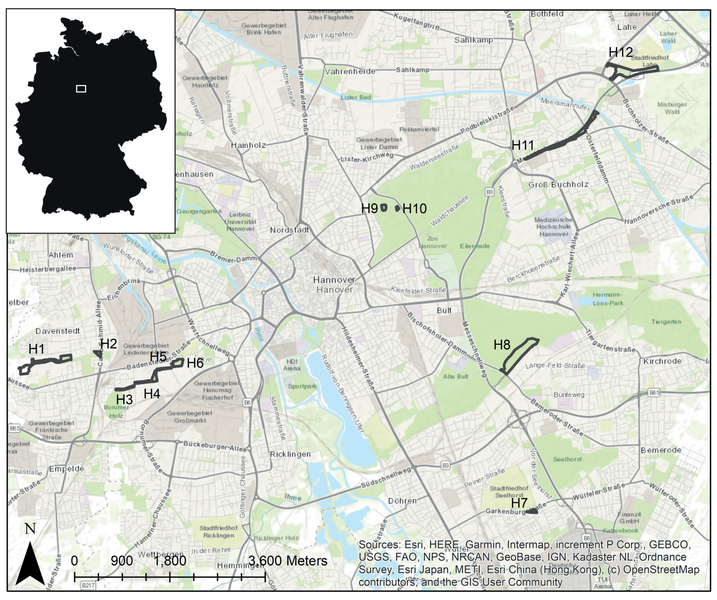
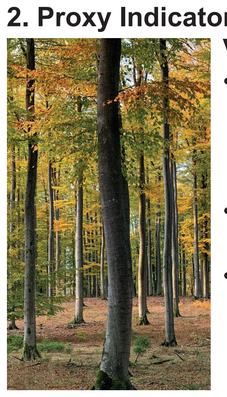


Figure 2: Map showing the boundaries of the sites selected for restoration in the city of Hannover.

METHOD (cont.)

2. Proxy Indicators for Ecosystem Health



Vegetation Structure | Land Cover

- Description: Supports habitat formation, species diversity, microclimate control and nutrient cycling (*Ashcroft et al., 2014; Lawley et al., 2016; Guo et al., 2017).*
- Data source: Land cover data from Sentinel-2A+B.
- Method: Five landscape classes: forest, low vegetation, built-up, bare soil and vegetation. Measure the change:

$$A_L = N_L \times A_c$$

Species Diversity | *Pieris napi*

- Description: Species diversity encompasses the variation in life and living organisms. Butterflies are proxy indicators for resource abundance and thus, environments that can support species diversity.
- Data source: Observation data of *Pieris napi* were retrieved from the Global Biodiversity Information Facility (GBIF).
- Method: Biodiversity Distribution Modelling.

Ecosystem Processes | *Leccinum scabrum*

- Description: Ecosystem processes are the fundamental functions supporting the survival of the ecosystem. Fungi are proxy indicators for nutrient cycling, a vital ecosystem process.
- Data source: Observation data of *Leccinum scabrum* were retrieved from the Global Biodiversity Information Facility (GBIF).
- Method: Biodiversity Distribution Modelling.

3. Biodiversity Distribution Modelling

This methodology allows the potential distribution of a species to be predicted based on a combination of the species' recorded observations and a number of environmental predictors. GBM was selected as the model for this analysis because its complexity allows it to better resemble reality (Li and Wang, 2013). The model requires presence data, pseudo-absence data, as well as environmental data to interpolate species distribution. The presence data were acquired from the GBIF. The pseudo-absence data were extrapolated in ArcGIS. Environmental data, at the finest spatial resolution available, were retrieved from various sources (Table 1) and visualised (Figure 3). The probability of species occurring in the project sites before and after the restoration project was calculated:

$$P_t = \frac{\sum_{i=1}^{n} P_{i_t}}{n}$$

Table 1: Metadata of the open-source environmental data sourced to be used as environmental predictors in the BDM.

Classification	Environmental Predictor	Year	Resolution (m)	Source
Topography	Elevation	N/A	830	(DIVA-GIS, 2011)
	Slope	N/A	830	(DIVA-GIS, 2011)
Land Cover	Land Cover	2016;2020	10	(Incora, 2021)
Meteorology	Maximum Temp.	1970-2000	1000	(WorldClim, 2020)
	Minimum Temp.	1970-2000	1000	(WorldClim, 2020)
	Average Temp.	1970-2000	1000	(WorldClim, 2020)
	Average Precip.	1970-2000	1000	(WorldClim, 2020)

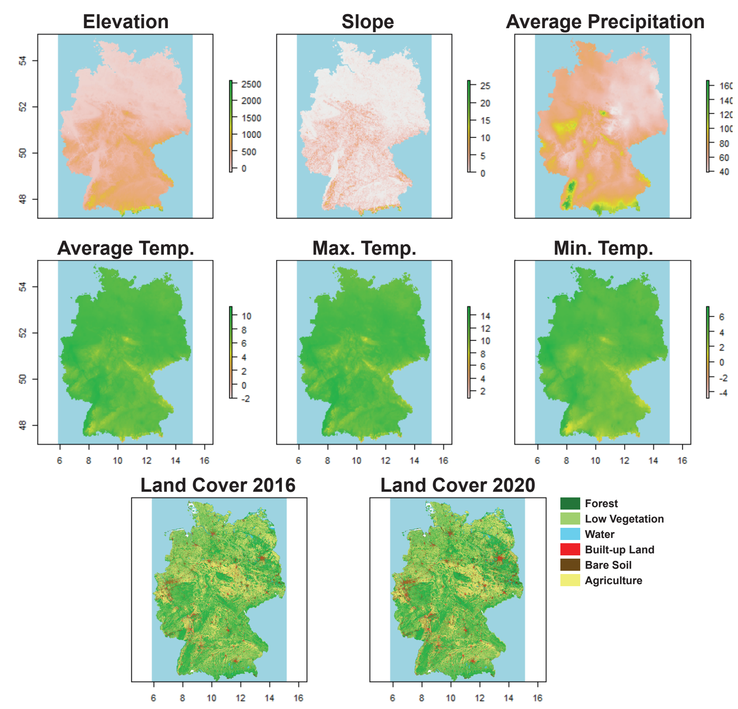


Figure 3: Visual representation of the topographical, meteorological and land cover conditions used in the BDM.

A_L = is the total area of each landscape class, *L*.
N_L = is the total number of cells classified as landscape, *L*.
A_C = the area of a single cell, which is a constant of 100 m^2.
P_t = The average probability of the species occurring in the buffered project boundary in each of the time periods, *t*.
P_{it} = the probability of the species occurring within 100 m^2 of cell, *i*, at time period, *t*.

RESULTS

1. Vegetation Structure | Land Cover

The results indicate that built-up land did not experience a significant change. Other landscape classes, including low vegetation, water, bare soil and agriculture experienced a reduction in total area. Agriculture in particular experienced a 60% decrease in area. Forest on the other hand, experienced an increase in area (+10%). It is thus inferred that other landscape classes were restored to forest cover. These results suggest that the restoration project was successful at bringing about a meaningful change to overall vegetation structure.

Table 2: Results of the land cover analysis to indicate vegetation structure

Landscape Class	2016 Land Cover (m^2)	2018 Land Cover (m^2)	Total Variance
Forest	919,900	1,007,700	10%
Low Vegetation	716,200	692,300	-3%
Water	17,800	8,900	-50%
Built-Up Land	465,900	465,700	0%
Bare Soil	32,000	30,200	-6%
Agriculture	88,500	35,500	-60%

2. Species Diversity | *Pieris napi*

The predictive accuracy of the model was evaluated and yielded an area under the curve (AUC) value of 0.8852, a correlation of 0.6733, a maximum true positive rate (TPR) and true negative rate (TNR) of 0.4798. The variance in the average probability of species occurrence for each site can be seen in Table 3. Most notable is the change in the probability of occurrence of *P. napi* in site H1 (+4.25%). Overall, *P. napi* is only 0.45% more likely to be distributed across project sites after the SWW project than before. Although small, this result is positive and suggests that the urban restoration project had a positive impact on the species diversity of the area

Table 3: Results of the distribution analysis for P. napi.

Site	Probability of Occurrence in 2016	Probability of Occurrence in 2020	Total Variance
H1	0.8116	0.8461	4.25%
H2	0.9392	0.0320	-0.67%
H3	0.9290	0.9344	0.57%
H4	0.8787	0.8787	0.00%
H5	0.8295	0.8380	1.02%
H6	0.9282	0.9282	0.00%
H7	0.9107	0.9139	0.35%
H8	0.8073	0.8001	-0.89%
Overall	**0.8793**	**0.8840**	**0.54%**

3. Ecosystem Processes | *Leccinum scabrum*

The AUC for this model was calculated to be 0. 9491, the correlation was 0.7924 and maximum TPR and TNR was 0.5326. Table 4 indicates the variance in the probability of species occurrence for each individual project site, as well as the project as a whole. Each project site experienced an increase in the mean probability of species occurrence, with the exception of H6 which is located in the city's forest park. The overall result was a 3.41% increase in the probability of *L. scabrum* occurring within the restored urban ecosystems. The results suggest that the restoration project successfully increased the presence of ecosystem processes.

Table 4: Results of the distribution analysis for L. scabrum.

Site	Probability of Occurrence in 2016	Probability of Occurrence in 2020	Total Variance
H1	0.5742	0.6415	11.72%
H2	0.5612	0.6133	9.28%
H3	0.5966	0.6209	4.07%
H4	0.7263	0.7263	0.00%
H5	0.7924	0.8062	1.74%
H6	0.8472	0.8472	0.00%
H7	0.5551	0.5679	2.32%
H8	0.5632	0.5707	1.33%
Overall	**0.6520**	**0.6743**	**3.41%**

CONCLUSION

The Climate-Biodiversity-Society nexus outlines various dependencies, interdependencies, connections, synergies, conflicts, and trade-offs that exist between human quality of life, climate change and the natural environment. Many of the issues presented are exacerbated in cities; however increased biodiversity and associated ecosystem services pose an opportunity to address a number of these issues concurrently. The results of the urban restoration project, 'Stadte Wagen Wildnis', were improved vegetation structure, increased species diversity and significantly enhanced ecosystem processes. These attributes suggest that the project brought about a positive change in ecosystem health as well as biodiversity and associated ecosystem services, and can thus be used to address the issues presented in the Climate-Biodiversity-Society nexus.

CONTACT INFORMATION

H. R. A. Pownall
07497880068
pownall.hannah@gmail.com
www.linkedin.com/in/hannah-pownall