Vegetation On Extensive Green Roofs With And Without Photovoltaic

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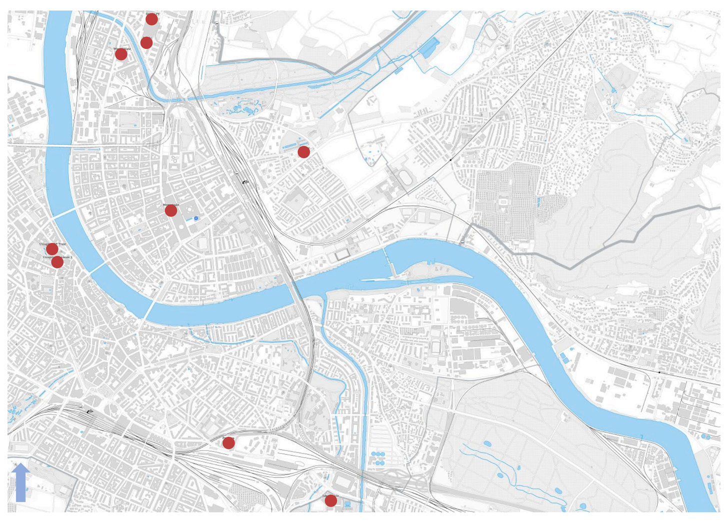
Motivation & Objectives

Urban expansion and densification are leading causes of natural habitat loss and a decline in biodiversity. To address these challenges, extensive green roofs can provide refuge for species adapted to extreme site conditions and serve as habitat and steppingstones for the survival of even endangered plants and animals. Additionally, the integration of photovoltaic (PV) systems with extensive green roofs offers the opportunity to generate renewable energy while simultaneously creating suitable habitats for flora and fauna. In this study, we conducted research on extensive green roofs with both homogeneous and heterogeneous structures including PV in Berlin and Basel. The primary objective was to gain insights into the ecological landscape of green roofs in these cities and to assess the quality of biodiversity of these extensive green roofs through vegetation surveys.

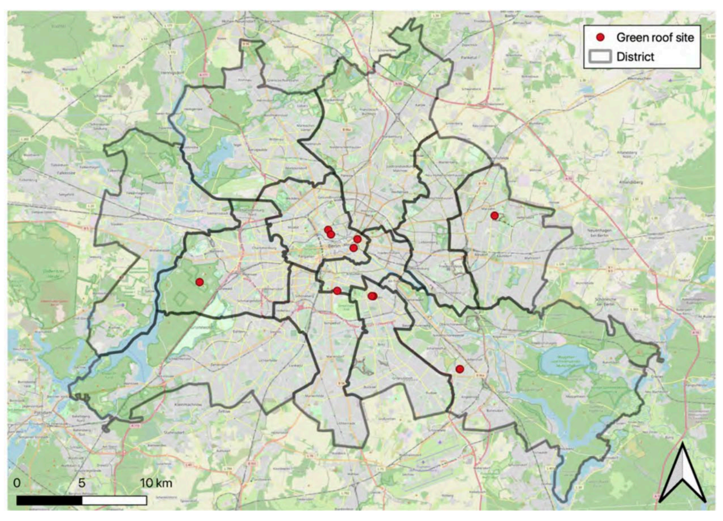
Basel, Switzerland

Basel is one of the cities with the highest green roof rate in the world (Brenneisen et al., 2020). The greening of unused flat roofs has been obligatory in Basel since 1999 and the city provides precise guidelines on how unused flat roofs on new buildings are to be greened and how an ecological compensation value can be created.

The climate is described as oceanic dry-warm with average annual temperature of 10.5 °C and average precipitation of 1274 mm/year (climate-data.org, 2023). Average precipitation in 2022 (survey year) was 847 mm/year and 12.6 the average year temperature (Statistik Basel, 2023).



Map of Basel with the investigated roofs (red dots). From top to bottom: Stücki PV, Stücki, BVB Tram, Eglisee, Messehalle, Universitätsspital OP-Trakt, Universitätsspital Klinikum2, Prodega, St. Jakobshalle. Scale 1:7500 Geoportal Basel.



Map of Berlin with the investigated roofs. From west to east: Ökowerk Grunewald, HU_CampusNord, HU_MensaNord, Saturn Alexanderplatz, Berliner Wasserbetriebe, Schwiebusserstrasse, Klunkerkranich, Neukölln Arcaden, HU_Adlershof Erwin-Schrödinger Zentrum 1 and 2 (ESZ1 and ESZ2), Gärten der Welt. QGIS-LTR Version 3.16.16, Basemap: Open Street Map.

Berlin, Germany

Berlin is one of the greenest cities in Germany and, where only in 2020 about 565 hectares of roof surfaces were greened (5.4 % of all roof surfaces; Pauligk et al., 2022). The GründachPLUS program funds the greening of roofs on existing buildings.

The climate is classified as warm and temperate, fully humid and with warm summers. The average annual temperature is 10.1°C, and the annual precipitation is around 669 mm/year (climate-data.org, 2023). In 2021 (survey year), Berlin was the warmest region in Germany with a mean annual temperature of 10.1 °C and the area with the lowest precipitation with 560 l/m² (Wetterdienst, 2023).

Methods

Basel, Switzerland, April 22 to June 30, 2022

A vegetation analysis was conducted on 9 non-irrigated, extensively greened roofs. The selected green roofs exhibited a wide range of heterogenous habitats, some of which included different types of photovoltaic installations.

The vegetation analysis was performed on 10 m² square plots on subjectively defined areas. In total, 27 areas on 9 extensive green roofs were investigated, resulting in a total of 108 plots (random selection of 4 plots per area).

Substrate height was measured on each plot as well as total plant coverage on each plot was estimated as a percentage. All vascular plant species within the plots were identified. Plant species growing outside the plots were not determined. Averaged indicator values (Landolt et al., 2010) were calculated using VEGEDAZ (Küchler, 2022) and the Shannon diversity indices were calculated over the mean value of each area in R.

Berlin, Germany, June 28 to 30, 2021

A vegetation analysis was carried out on 11 green roofs in Berlin, ten of which were classified as extensive. One green roof (Klunkerkranich) was automatically irrigated and therefore classified as semi-intensive. Differences between solar green roofs and roofs without photovoltaics were not considered.

Substrate height was measured on each roof and the total plant coverage within the plot was estimated as a percentage of the total plot area. The plant species within the plots were identified as well as all plant species of the entire green roof were documented in order to create a list of all species per roof. The averaged Landolt indicator values (2010) were calculated using VEGEDAZ (Küchler, 2022) and the Shannon indices were calculated in R.

Basel and Berlin

For visualisation, a PCA (Principal Component Analysis) (Leyer & Wesche, 2007) was calculated in R, where the following variables were included: number of plant species, Shannon indices, plant coverage, substrate height as well as the indicator values moisture, nutrient, reaction, light, continentality and temperature.

HU_Adlershof (ESZ1) Berlin

StückiKies_13 Basel

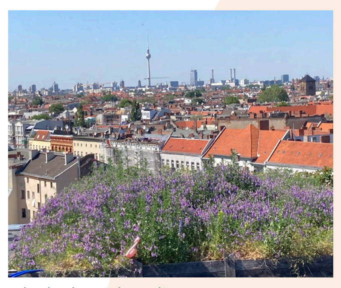
Gärten der Welt Berlin

Eglisee_Flach Basel

Universitätsspital Klinikum 2 Basel (all areas)

BVBTram_W_Tief und BVBTram_W_Hoch Basel

Jakob_Kompost Basel



Klunkerkranich Berlin

Stücki_PV15 Basel

Results and Discussion

In total, 297 different plant species were identified on 20 green roofs in Basel and Berlin. Of these, 90 species occurred both in Berlin and Basel, while 99 species were present only in Berlin and 108 species only in Basel.

Basel

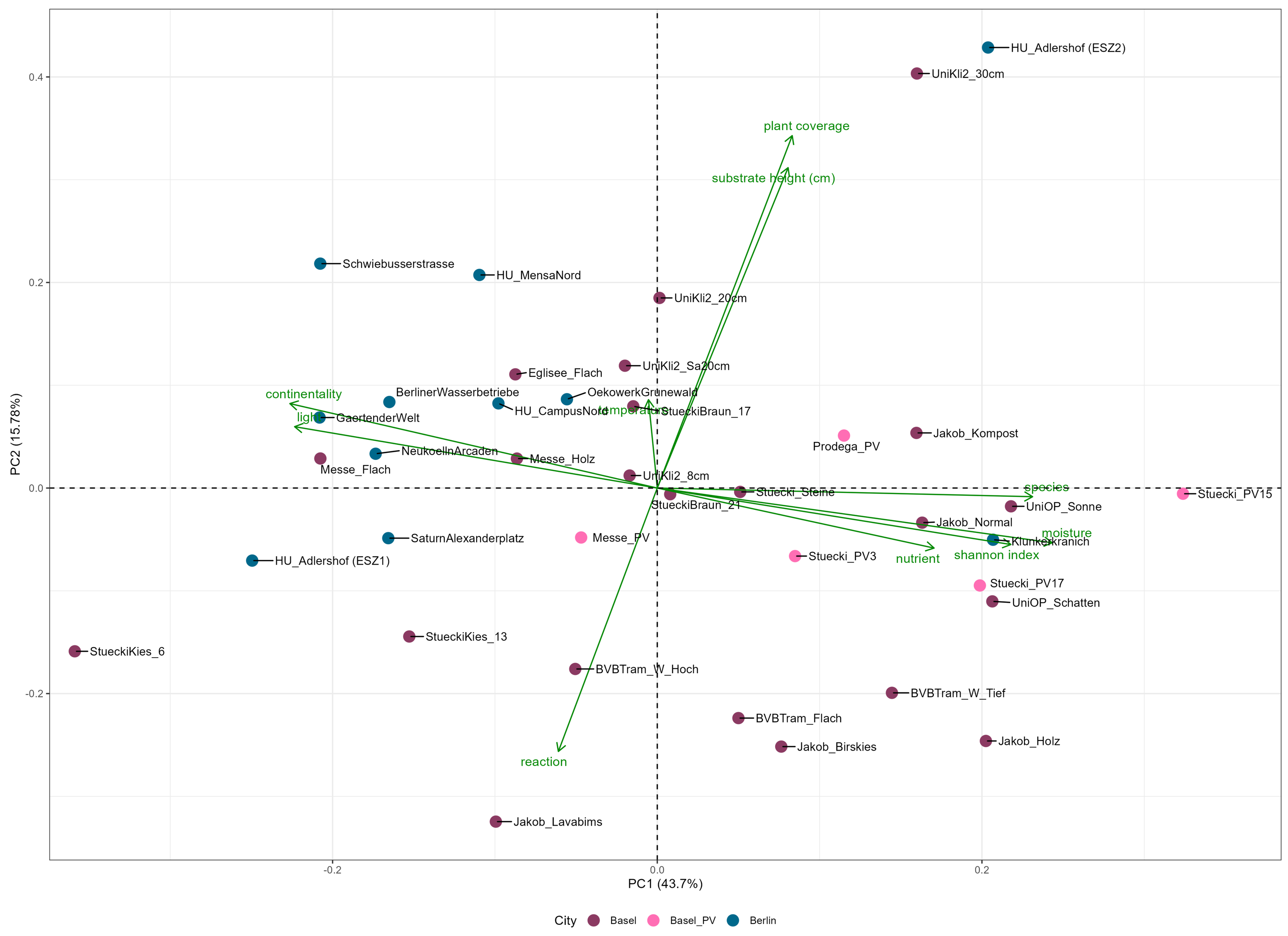
We identified 198 vascular plant species on 9 green roofs. The number of plant species ranged from 14 species on the StueckiKies_6 area (one plot with only 2 species) that had low substrate height and no habitat heterogeneity, to 64 species on the Stuecki_PV15 area (one plot with already 40 species) on a structurally rich, substrate-heterogeneous roof.

Berlin

We determined 189 vascular plant species on 11 green roofs. The species numbers ranged from 17 on Neukölln Arcaden with low substrate height and no habitat heterogeneity, to a maximum of 68 different plant species on the diverse, semi-intensive Klunkerkranich roof.

PCA

A PCA was performed with 10 variables, which are shown as loadings (green arrows) on the plot to the right. The Principal Component (PC) 1 explained 44 % of the variance in the vegetation data, while PC 2 explained 16 %. Blue circles indicate roofs in Berlin, dark red circles roofs in Basel and pink circles roofs in Basel with photovoltaic installations.



A Principal Component Analysis (PCA) was calculated with 10 variables, such as plant species related variables like indicator values and roof characteristics. All investigated roofs are visualized along their separation in a two-dimensional space of PC1 and PC2. The different variables (the loadings shown as green arrows) strongly correlate with one of the two dimensions to explain their influence on the respective roofs. Dark red and pink circles = roofs in Basel, pink with photovoltaics installations. Blue circles = roofs in Berlin

The PCA plot visualizes species richness on the roofs, where roofs with a higher species diversity such as Stücki_PV15 in Basel are located on the right side of the PCA plot and positive PC 1 values correlated with higher species number and larger Shannon indices. This higher species richness is explained by larger moisture and nutrient indicator values, which both are required to maintain a more diverse set of plant species on a roof. In contrast, continentality and light indicator values are negatively correlated with species number and indicate that only a limited, highly specialized number of plant species are adapted to drier roofs with larger temperature fluctuations. Therefore, the StückiKies_6 area in Basel shows the lowest plant diversity of all investigated roofs.

Principal component 2 is positively correlated with plant coverage and substrate height. Both variables indicate that humus-rich roofs have good plant coverage, while the reaction indicator value is negatively correlated. This points to the fact that humus-rich roofs are characterized by soils with rather low pH values, while the soil with negative PC2 values have a more basic pH value. Most roofs with photovoltaics installations (Basel_PV, pink circles) exhibited a high species richness, which indicates that PV installations do not decrease plant diversity.

Echium vulgare appears on green roofs in Basel and Berlin and is a good pollinator plant for many wildbee species

Teucrium botrys appears on both roofs Stücki and Stücki_PV in Basel

Highlights & Conclusion

Our vegetation analyses on a diverse set of extensive green roofs with and without photovoltaics in Basel and Berlin have shown that habitat diversity and substrate heterogeneity of extensive green roofs increase the biodiversity of plant communities, which even included endangered plant species.

When designing a biodiverse extensive green roof (with and without photovoltaics), it is important to consider that substrate heterogeneity and structural richness are essential. Extensive and professional maintenance and the use of local plants adapted to the extreme roof conditions are vital to establish a dynamic self-sustaining vegetation while at the same time making full use of regenerative energy production. **Therefore, we recommend promoting heterogenous extensive green roofs as a diverse habitat for flora and fauna.**

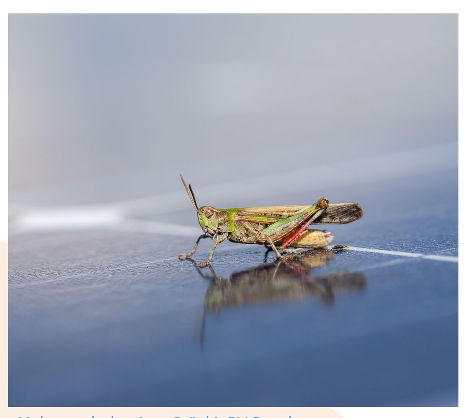
Gossamer-winged butterfly (Lycaenidae) at HU_Adlershof ESZ2 in Berlin

Allium carinatum found at Ökowerk Grunewald Berlin

Ophrys apifera, a native orchid on UniKl2_8cm Basel

Elevated PV installation Stücki_PV Basel with local grassland vegetation

Dianthus carthusianorum appears on green roofs in both cities Basel and Berlin



Aiolopus thalassinus Stücki_PV Basel

Calliptamus italicus at Ökowerk Grunewald Berlin

Cladonia sp. at Ökowerk Grunewald Berlin

References:

Brenneisen, S., Knobel, B., & Kopf, A. (2020). Basel-Stadt: Grüne Dächer als urbane Lebensräume auch bei Hitze. *Zürcher Umweltpraxis und Raumentwicklung (ZUP), 26*, 39-42.

climate-data.org. (2023a and b). *Basel and Berlin climate: Temperature & Weather*

Küchler, M. (2022). *VEGEDAZ.* (Version 2022).

Landolt, E. et. al. (2010). *Flora indicativa* (Vol. 2). Haupt.

Leyer, I., & Wesche, K. (2007). *Multivariate Statistik in der Ökologie*. Springer Berlin.

Pauligk, A., et. al. (2022). *Erhebung und Aufbereitung von Informationen zum Gründachbestand in Berlin 2020.*

Deutscher Wetterdienst (2021). *Deutschlandwetter im Jahr 2021.*

Statistik Basel (2023). www.statistik.bs.ch/zahlen/tabellen/2-raum-landschaft-umwelt.html.

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