

EFFECTIVENESS OF GREEN ROOFS IN STRENGTHENING ECOLOGICAL NETWORK

Mitali Yeshwant Joshi*¹, Lucie Rivière², Grégory Mahy², Jacques Teller¹

¹ LEMA, Urban and Environmental Engineering Department, University of Liege, Belgium – mjoshi@uliege.be, jacques.teller@uliege.be

² Biodiversity and Landscape, TERRA Teaching and Research Center, Gembloux Agro-Bio Tech, University of Liege, Gembloux, Belgium – lucie.reviere@uliege.be, g.mahy@uliege.be

Commission IV, WG IV/10

KEY WORDS: Green roofs, ecological networks, urban biodiversity, GIS, smart cities, sustainability

ABSTRACT:

Improving biodiversity in urban areas is widely recognised as part of sustainable smart cities development framework. Due to unprecedented urbanisation, there is a lack of adequate green spaces which has in turn affected the urban biodiversity. Green roofs are argued to enhance and support the biodiversity by systematic inclusion into the urban ecological network. However, its connection to the existing natural ecological areas and connectivity are not discussed at a city scale. Thus, in this study, we aim at identifying the connectivity of potential areas for developing green roofs in strengthening the biodiversity and ecological network in cities. Altogether, we observe that the potential roofs are in the near proximity of these zones. The zones with dry lawns and meadows like environment are quite limited and spatially far from each other. Thus, developing green roofs can help in connecting these spaces. In this paper, we mainly focused on bees as they play an important role in pollination and are also declining in the urban areas. Further research can incorporate more detailed analysis on foraging distances of other species. A methodology can be developed to select which zones can be targeted for specific species.

1. INTRODUCTION

Improving biodiversity in urban areas is now widely recognised as part of sustainable smart cities development framework (Benvenuti, 2014). Due to unprecedented urbanisation, there is a lack of adequate green spaces which has in turn affected the urban biodiversity. Urban green infrastructure is often suggested as a solution to improve biodiversity. However, its connection to the existing natural ecological areas and connectivity are not discussed at a city scale. In this study, we focus particularly on green roofs.

Extensive green roofs have a relatively thin layer of a light-weight substrate, which needs little or no additional structural support (Berardi et al., 2014). The species planted on EGR are mostly dry grass, succulents, herbs and mosses (Getter & Rowe, 2006). In dense urban areas, biodiversity is more fragmented and isolated. It is essential to plan ecological corridors to facilitate the dispersal of species between environments (Mayrand & Clergeau, 2018).

Ecological network is usually studied in order to plan the ecological corridors in urban areas. Ecological network can be defined as “A coherent system of natural and/or semi-natural landscape elements that is configured and managed with the objective of maintaining or restoring ecological functions as a means to conserve biodiversity while also providing appropriate opportunities for the sustainable use of natural resources” (Bennett, 2004, pg.5). The ecological network is divided into a coherent system of areal components as shown in the figure 1. Core areas are the areas where preservation of biodiversity is of prime importance. The corridors are to maintain the vital ecological or environmental connections. The buffer zone is to protect the network from potentially damaging external damages. Sustainable use areas are the areas where there is

enough opportunity for both exploitation of natural resources and maintenance of ecosystem functions (Bennett, 2004; Froment, 2017).

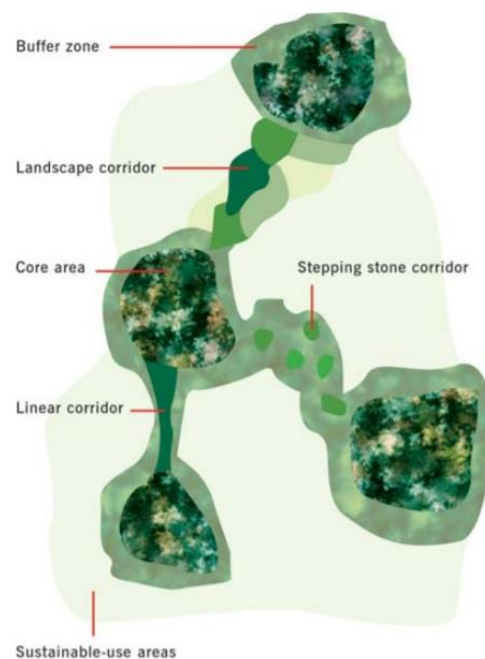


Figure 1. Components of ecological network (Bennett, 2004)

Green roofs are argued to enhance and support the biodiversity, and they can be highly effective if they are included in an ecological network (Joimel et al., 2018). Green roofs provide

*Corresponding author

habitats and food to many species (Oberndorfer et al., 2007; Schindler et al., 2011). They are often inaccessible, thus offering an undisturbed habitat. Various species such as birds, spiders, bees and arthropods are observed on green roofs (Fernandez-Canero & Gonzalez-Redondo, 2010; Parkins & Clark, 2015; Williams et al., 2014). However, their richness and abundance are dependent on various factors such as plant diversity, proximity of green roofs to other green roofs or green spaces, height and area of the roof (Mayrand & Clergeau, 2018). Research has shown that green roof arthropod diversity is observed to increase with better connectivity between the green spaces (Braaker et al., 2017). Green roofs located in close proximity to each other and near the existing green biodiversity rich areas can improve the abundance of species in urban areas.

Currently, the population of bees, arthropods and collembolas are observed to reduce in the urban areas. Utilizing green roofs to regulate their presence can strengthen the ecological network and also integrate the dense urban areas with nature. However, understanding the potential areas for green roofs along with the ecological network is an essential prelude to utilizing green roofs in biodiversity enhancement. Therefore, in this study, we aim at identifying the connectivity of potential areas for developing green roofs in strengthening the biodiversity and ecological network in cities.

2. METHODOLOGY

2.1 Study Area

Liege, a city in Wallonia region of Belgium, is the third-most populous city of Belgium with a total of 195,965 inhabitants and area around 69 km². There are 136,170 buildings in the city, with a total area of building roofs about 10 km², which represents around 14% of the city area.

2.2 Computing potential of green roofs

Green roof potential was estimated based on the methodology explained by Joshi et al. (2020) for the city of Liege. We mainly consider flat roofs more suitable for green roof development. Apart from this, the reserved structural capacity of buildings was considered based on the height of the building where taller buildings were concrete (more strength) and shorter buildings were steel based. The steel structure buildings were then classified based on the year of construction. The structure of the buildings was indeed corresponding to the norms that were in place during the period of construction. The buildings built before 1977 have more strength than required as they were built according to old standards, which were more conservative due to lower accuracy and precision. The Eurocode was proposed in the year 1977 after which the buildings were built with exact strength and capacity due to advancement in the technology. It is not possible to develop green roofs on these recent buildings without major structural changes. Therefore, we consider buildings with steel structure that are constructed before 1977 for implementing green roofs (Joshi et al., 2020).

2.3 Analysing ecological networks

Public Service of Wallonia (SPW) launched a program called plan for development of nature in cities/ Plan communal de Développement de la Nature (PCDN) in 1995 for municipalities in Wallonia region. Amongst the cities in Wallonia selected for PCDN, Liege is the most urbanised and populated city, which therefore requires a very particular approach for nature

conservation. In the PCDN, which was drafted in 2016 (Lebeau et al., 2016), a detailed ecological network of city of Liege is developed by the Biodiversity and Landscape unit of Gembloux Agro-Bio Tech (ULg), in collaboration with the ICEDD (Institute for Consulting and Studies in Sustainable Development) and the collective Ipé (Interface for study projects) for urban planning aspects. The ecological network of Liege is mainly divided into four parts, namely, central zone (ZC), central zone restorable (ZCr), development zone (ZD), and development zone in urban area (ZD_Urb). These zones are further divided into open environments characterizing different habitats such as moors, meadows, dry lawns, agricultural areas, forests and water bodies.

The central zone is of great biological interest where everything should be in favour of nature conservation. The restorable zone is identified as interesting for certain target species that require restoration. The development zone is the area with less biological interest but has a significance. This zone is mainly with urban components such as cemeteries, storm basins and golf courses which have potential in terms of biodiversity. The development zones in urban areas are the artificial habitats such as small green growth on railway tracks, which are similar to natural or semi-natural habitats. Figure 2 indicates the map with all the zones along with existing built-up of Liege.

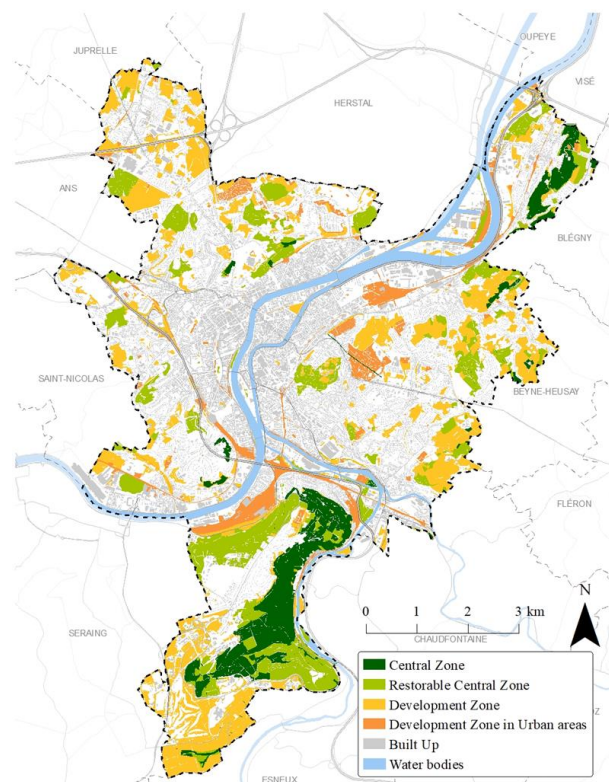


Figure 2. Zones in ecological network of Liege along with built-up (Source - ecological network: PCDN de la Ville de Liège, IGN-Top10v et Smartpop)

As green roofs are observed to have ecosystems similar to dry lawns and meadows (not frequently), we consider only these two environments in our analysis. We also consider potential roofs with greater than 100 square meter area. We calculate the distance between the potential green roofs and the distance between ecological network zones (dry lawns and meadows environment) and potential green roofs. This was done using near distance tool in ArcGIS Pro 2.7. We consider bees in

particular in this study as they play an important role in pollination and they are also declining in the urban areas. Foraging range of small bees is around 100-200 m and large bees is around 1000m (Zurbuchen et al., 2010). Although reported foraging distance of bees is 1000m, we consider 1500 m threshold in this analysis. Height of the buildings is also observed to impact the abundance and richness of these species, we report and discuss the statistics of height of potential roofs.

3. RESULTS

There are a total of 6521 buildings (346 hectares) with potential for green roofs with an area greater than 100 square meters in the city of Liege. The distance between the potential green roofs located within 1500 m of each other is on an average around 930 m, ranging from 567 m to 1281 m. The minimum distance between the potential roofs is 2 m with a maximum of 355 m. This suggests that the potential green roofs are closer to each other if the target is to increase the spotting of bees. The closeness of potential roofs is also visible in figure 3.

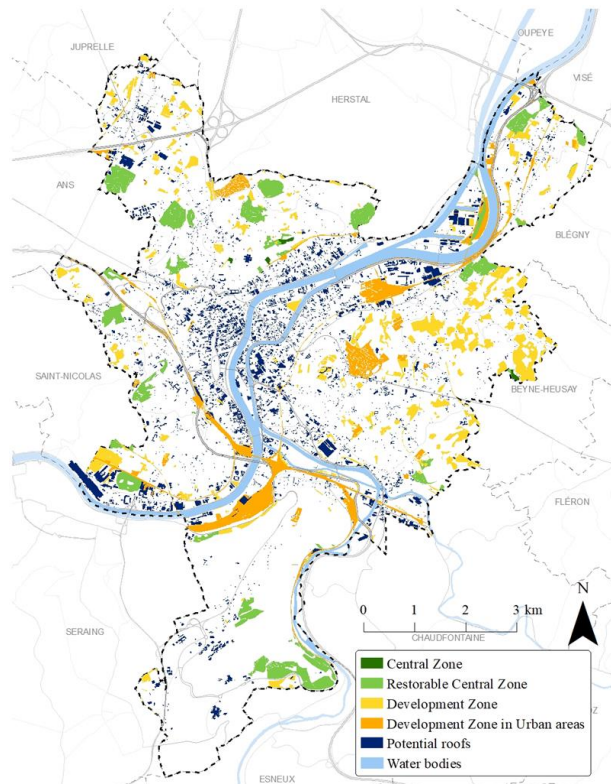


Figure 3. Ecological network zones with dry lawns and meadows environment (Source - ecological network: PCDN de la Ville de Liège, IGN-Top10v et Smartpop)

The central zone has total 6 sites with dry lawns and meadows. Each site has around 176 to 1520 potential roofs (average: 959) in the proximity of 1500 m. The average distance between potential roofs to the dry lawns and meadows in central zone is 1044 m, with a minimum of 949 and maximum of 1080 m. The minimum distance between potential roofs and dry lawns and meadows in the central zone is around 54 m on an average with a minimum of 6 m and maximum of 159m.

There is total 389 sites in the restorable central zone. Each site has around 448 (6 to 1664) potential roofs within a distance of 1500 m. The average distance between potential roofs to the dry

lawns and meadows in restorable central zone is 1004 m, with minimum distance of 567 m and a maximum of 1302 m. The minimum distance between green roofs and central zones with dry lawns and meadows is around 104 m on an average, with a maximum of 710 m. Also, the central zone sites are quite far from each other. Thus, the potential roofs near to these sites can be designed with species that are specific to the central zone to enhance biodiversity.

A total of 627 sites are observed in the development zone with dry lawns and meadows environment. Each site has around 23 to 2242 potential roofs, 516 on an average in the proximity of 1500 m. The average distance from sites with dry lawns and meadows in development zone to potential roofs is around 980 m, with a minimum of 540 m and maximum of 1290 m. The average minimum distance between these sites and potential roofs is around 65 m with a maximum of 940 m.

There is a total of 1306 sites in the development zone of urban area with dry lawns. There are no sites with meadows environment as this region is quite disconnected with the central zone. Around 8 to 2211 potential roofs (average:779) are within 1500 m of these sites. The average distance between these sites to the potential roofs nearby is 974 m, with a minimum of 524 m and maximum of 1276 m. The minimum distance between these sites and potential roofs nearby on an average is 58 m, with a maximum of 500m.

On an average, the height of the buildings where green roofs can be implemented is around 8 m, with a maximum of 80 m and a minimum of 3 m. Most of the buildings are with a height less than 20 m. Braaker et al. (2017) observed no impact of height on the abundance of species, this was partly due to sample with height less than 18 m. However, some studies point out that with increase in height, there is a lower number of species observed (Kyrö et al., 2018; Madre et al., 2013). Around 703 buildings out of 6521 with potential of greening are with a height greater than 20 m. These buildings need to be studied further for implementing green roofs in order to enhance biodiversity. As most of the roofs are less than 20 m, they can be useful in strengthening the ecological network.

Altogether, we observe that the potential roofs are in the near proximity of these zones. The zones with dry lawns and meadows like environment are quite limited and spatially far from each other. Thus, developing green roofs can help in connecting these spaces. Moreover, the minimum distances between potential green roofs and ecological network zones along with distance within potential green roofs are less than 200 m. This means that the potential roofs can be favourable for both small and large bees.

Further research can incorporate a more detailed analysis of area and height of potential green roofs within a buffer zone of the ecological network sites. It can also include in depth study of specific characteristics of these zones to ensure a better selection of species on green roofs. More detailed analysis on foraging distances of other species also can be done. A methodology can be developed to select which zones can be targeted for specific species.

ACKNOWLEDGEMENTS

The research was funded through the ARC grant for Concerted Research Actions for project number 19/23-28 “CityRoof” financed by the French Community of Belgium (Wallonia-Brussels Federation).

REFERENCES

- Bennett, G. 2004. Integrating Biodiversity Conservation and Sustainable Use Lessons Learned From Ecological Networks. Cambridge, UK: IUCN, Gland, Switzerland, and Cambridge, UK, in collaboration with Syzygy, Netherlands.
- Benvenuti, S. 2014. Wildflower green roofs for urban landscaping, ecological sustainability and biodiversity. *Landscape. Urban. Plan.*, 124, 151–161. <https://doi.org/10.1016/j.landurbplan.2014.01.004>
- Berardi, U., GhaffarianHoseini, A., GhaffarianHoseini, A. 2014. State-of-the-art analysis of the environmental benefits of green roofs. *Appl. Ener.*, 115, 411–428. <https://doi.org/10.1016/j.apenergy.2013.10.047>
- Braaker, S., Obrist, M. K., Ghazoul, J., Moretti, M. 2017. Habitat connectivity and local conditions shape taxonomic and functional diversity of arthropods on green roofs. *J. Anim. Eco.*, 86(3), 521–531. <https://doi.org/10.1111/1365-2656.12648>
- Fernandez-Canero, R., Gonzalez-Redondo, P. 2010. Green roofs as a habitat for birds: A review. *J. Anim. Vet. Adv.*, 9(15), 2041–2052. <https://doi.org/10.3923/javaa.2010.2041.2052>
- Froment, C. 2017. Arthropods communities on green roofs in Brussels: Influence of roof vegetation and landscape context . Retrieved from Université de Liège, Liège, Belgique website: <https://matheo.uliege.be/handle/2268.2/3001>
- Getter, K. L., Rowe, D. B. 2006. The role of extensive green roofs in sustainable development. *HortScience*, 41(5), 1276–1285. <https://doi.org/10.21273/hortsci.41.5.1276>
- Joimel, S., Grard, B., Auclerc, A., Hedde, M., Le Doaré, N., Salmon, S., Chenu, C. 2018. Are Collembola “flying” onto green roofs? *Ecol. Engg.*, 111, 117–124. <https://doi.org/10.1016/j.ecoleng.2017.12.002>
- Joshi, M. Y., Selmi, W., Binard, M., Nys, G.-A., Teller, J. 2020: Potential for urban greening with green roofs: A way towards smart cities. *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.* VI-4-W2, 87-94 <https://doi.org/10.5194/isprs-annals-VI-4-W2-2020-87-2020>
- Kyrö, K., Brenneisen, S., Kotze, D. J., Szallies, A., Gerner, M., Lehvavirta, S. 2018. Local habitat characteristics have a stronger effect than the surrounding urban landscape on beetle communities on green roofs. *Urban. Forestry. Urban. Greening.*, 29, 122–130. <https://doi.org/10.1016/j.ufug.2017.11.009>
- Lebeau, J., Séleck, M., Mahy, G. 2016. Rapport relatif à l’actualisation de l’étude et de la cartographie du réseau écologique du territoire de l’entité du Plan communal de Développement de la Nature de la Ville de Liège Tranche I: Actualisation de l’inventaire du Plan communal de Développement. Liege, Belgium: Ville de Liege/PCDN
- Madre, F., Vergnes, A., Machon, N., Clergeau, P. 2013. A comparison of 3 types of green roof as habitats for arthropods. *Ecol. Engg.*, 57, 109–117. <https://doi.org/10.1016/j.ecoleng.2013.04.029>
- Mayrand, F., Clergeau, P. 2018. Green Roofs and Green Walls for Biodiversity Conservation: A Contribution to Urban Connectivity? *Sustainability*, 10(4), 985. <https://doi.org/10.3390/su10040985>
- Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., ... Rowe, B. 2007. Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services. *BioScience*, 57(10), 823–833. <https://doi.org/10.1641/b571005>
- Parkins, K. L., Clark, J. A. 2015. Green roofs provide habitat for urban bats. *Global Ecol. Conserv.*, 4, 349–357. <https://doi.org/10.1016/j.gecco.2015.07.011>
- Schindler, B., Griffith, A., Jones, K. 2011. Factors Influencing Arthropod Diversity on Green Roofs. *Cities and the Environment (CATE)*, 4(1). Retrieved from <https://digitalcommons.lmu.edu/cate/vol4/iss1/5>
- Williams, N. S. G., Lundholm, J., Scott Macivor, J. 2014. Do green roofs help urban biodiversity conservation? *Journal of Appl Ecol.*, 51(6), 1643–1649. <https://doi.org/10.1111/1365-2664.12333>
- Zurbuchen, A., Landert, L., Klaiber, J., Müller, A., Hein, S., Dorn, S. 2010. Maximum foraging ranges in solitary bees: only few individuals have the capability to cover long foraging distances. *Biological. Conserv.*, 143(3), 669–676. <https://doi.org/10.1016/j.biocon.2009.12.003>